BBC

HOW EVOLUTION CREATED VAMPIRES

Science Focus

The spacecraft that
NASA SMASHED INTO AN ASTEROID

Secrets of
THE FUNGUS AMONG US

Why positive thinking
BOOSTS YOUR PHYSICAL HEALTH

FIRST CONTACT

AN ALIEN SIGNAL IS DISCOVERED. WHAT HAPPENS NEXT?

SF
SCIENCEFOCUS.COM
#383 OCT 2022
UK£5.50 US$11.50 CAN$13.99
AUS$13.50 NZ$19.99

IN THIS ISSUE

Psychology
Why men lose friends and how it hurts their health

Dark matter
So what if we can't figure out what it actually is?

Environment
What we can do about sewage in our waters

This was Sylvia's promise to you...

A generation ago, a woman named Sylvia made a promise. As a doctor's secretary, she'd watched stroke destroy the lives of so many people. She was determined to make sure we could all live in a world where we're far less likely to lose our lives to stroke.

She kept her promise, and a gift to the Stroke Association was included in her Will. Sylvia's gift helped fund the work that made sure many more of us survive stroke now than did in her lifetime.

Sylvia changed the story for us all. Now it's our turn to change the story for those who'll come after us.

Stroke still shatters lives and tears families apart. And for so many survivors the road to recovery is still long and desperately lonely. If you or someone you love has been affected by stroke – you'll know just what that means.

But it doesn't have to be like this. You can change the story, just like Sylvia did, with a gift in your Will. All it takes is a promise.

You can promise future generations a world where researchers discover new treatments and surgeries and every single stroke survivor has the best care, rehabilitation and support network possible, to help them rebuild their lives.

Big or small, every legacy gift left to the Stroke Association will make a difference to stroke survivors and their families.

Find out how by calling 020 7566 1505

or email legacy@stroke.org.uk

or visit stroke.org.uk/legacy

Rebuilding lives after stroke

The Stroke Association is registered as a charity in England and Wales (No 211015) and in Scotland (SC037789).
Also registered in the Isle of Man (No. 945) and Jersey (NPO 369), and operating as a charity in Northern Ireland.

Stroke Association

FROM THE EDITOR

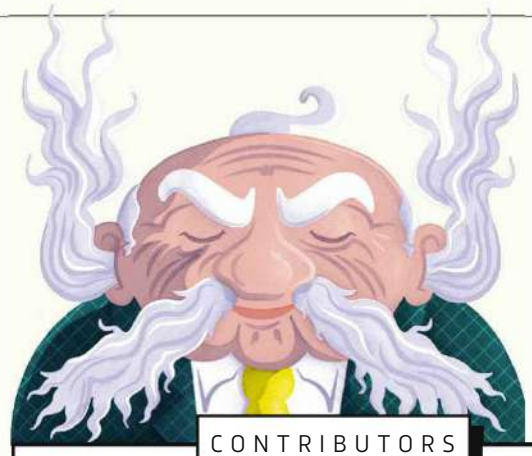
It started with *E.T.* It's the first film I can remember. My cousin sat me in front of a TV, slotted the tape into the VHS player and that was that: I fell in love with movies about aliens. Years later, a science teacher (who I now realise might have been feeling the after-effects of a big night out) darkened the room and put *Independence Day* on laser disc into the TV on wheels to silence a classroom full of 12-year-olds. It worked, and I realised then that aliens may not be so friendly after all. And then I watched *Alien*.

As any aficionado of extraterrestrials will tell you, it doesn't tend to end well for us when we cross paths with beings from another planet. We usually end up eaten, enslaved or extinct. And, yet these warnings haven't stopped scientists from seeking out ET. Maybe it's because fiction tends to hold up a mirror to ourselves, revealing our own instincts and insecurities. Or, maybe it's because the discovery of an alien signal would be the most profound moment in our entire history: it would mean Earth was not a one-off. Either way, whether you like to think of aliens as benevolent, waddling potato sacks, or invading, stabby insectoids, we are now scanning more of the cosmos with more sophisticated tech than ever before. The search for extraterrestrial intelligence has arguably never been so big.

So it begs the question: what would actually happen if we spotted an alien signal in the ether? Dr Stuart Clark digs into the drama over on p60. And don't miss the incredible BBC film on this very subject, *First Contact*, when it hits our screens in October.

Daniel Bennett, Editor

WANT MORE? FOLLOW **SCIENCEFOCUS** ON FACEBOOK TWITTER PINTEREST INSTAGRAM



Why does nasal and ear hair become more prominent as you age? →p80

CONTRIBUTORS

DR KATIE MACK
Dark matter outweighs the visible stuff six to one, yet we still don't know what it's made of. Cosmologist Katie reveals why that doesn't keep her up at night. → p32

DR DEAN BURNETT
The UK grieved together over the death of the Queen. Neuroscientist Dean explains why national mourning is such a fundamental part of being human. → p40

DR BRITTNEY BOROWIEC
Biologist and zoologist Brittney gets stuck in to the grisly world of vampirism, just in time for Halloween. → p52

DR HELEN PILCHER
Did you know that, genetically, we're more like fungi than plants? If not, then you might want to check out biologist Helen's guide to the fungal world. → p82

CONTACT US

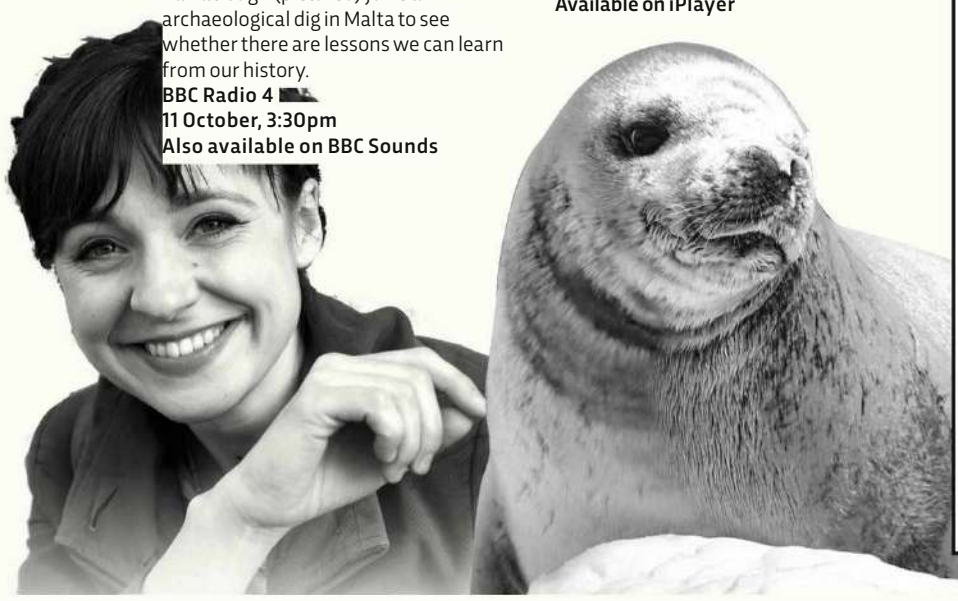
Advertising
David.DSouza@ourmedia.co.uk
0117 300 8110
Letters for publication
reply@sciencefocus.com
Editorial enquiries
editorialenquiries@sciencefocus.com
0117 300 8755
Subscriptions
buysubscriptions.com/contactus
03330 162 113*
Other contacts
sciencefocus.com/contact

ON THE BBC THIS MONTH...

People Fixing The World: Sustainability In Death
We're running out of space for the dead. Cremation releases hundreds of kilos of CO_2, and traditional burials leach poisons into ground. The team explores the cutting-edge, sustainable alternatives out there.
BBC World Service
11 October, 3pm
Also available on BBC Sounds

Costing The Earth: The Prehistoric Hitchhiker's Guide To Climate Change
How did early humans survive a changing climate? Eleanor Rosamund-Barraclough (pictured) joins an archaeological dig in Malta to see whether there are lessons we can learn from our history.
BBC Radio 4
11 October, 3:30pm
Also available on BBC Sounds

Frozen Planet II
If you can withstand the heartache, the new series will be available on iPlayer in its entirety. Just watch through your fingers when you see a baby seal on screen...
Available on iPlayer



COVER: ANDY POTTS THIS PAGE: GETTY IMAGES, SHUTTERSTOCK, TIM FLACH/BBC, DANIEL BRIGHT

*UK calls will cost the same as other standard fixed line numbers (starting 01 or 02) and are included as part of any inclusive or free minutes allowances (if offered by your phone tariff). Outside of free call packages call charges from mobile phones will cost between 3p and 55p per minute. Lines are open Mon to Fri 9am-5pm. If calling from overseas, please call +44 1604 973721. *BBC Science Focus* (ISSN 0966-4270) (USPS 015-160) is published 14 times a year (monthly with a Summer issue in July and a New Year issue in December) by Our Media Company, Bristol, Eagle House, Bristol, BS1 4ST. Distributed in the US by NPS Media Group, 2 Enterprise Drive, Suite 420, Shelton, CT 06484. Periodicals postage paid at Shelton, CT and additional mailing offices. POSTMASTER: Send address changes to *BBC Science Focus*, PO Box 37495, Boone, IA 50037-0495.

CONTENTS

REGULARS

06 EYE OPENER
Stunning pictures from around the world.

10 CONVERSATION
See what's been in our inbox this month

13 DISCOVERIES
Perseverance rover finds organic material on the Red Planet; microbreaks could help prevent workplace burnout; blue light from your phone screen could be ageing you; parasite obtained from fossilised Viking poo has genome mapped; air pollution could trigger lung cancer in non-smokers; an ancient moon may have formed Saturn's iconic rings; newly-discovered extinct reptile could shed light on tuatara evolution.

28 DR RADHA MODGIL
Why positive thinking is good for your body and your brain.

30 DR KATE DARLING
The prickly issue of 'who's responsible' if you have an accident in a self-driving car.

32 DR KATIE MACK
We still don't know what dark matter is, but that's okay.

36 REALITY CHECK
The science behind the headlines. What is our inner child? Why is sewage being pumped into the UK's waters? Why do we experience grief over the death of someone we've never met?

43 INNOVATIONS
The latest tech news.

75 Q&A
Our experts answer this month's questions. How do cats know when it's about to rain? What is the Maillard reaction? How soon can you catch COVID again? What is white, pink and brown noise?

82 EXPLAINER
Find out everything you wanted to know about yeasts, moulds and mushrooms.

88 CROSSWORD
Our cryptic crossword is like a gym for your brain.

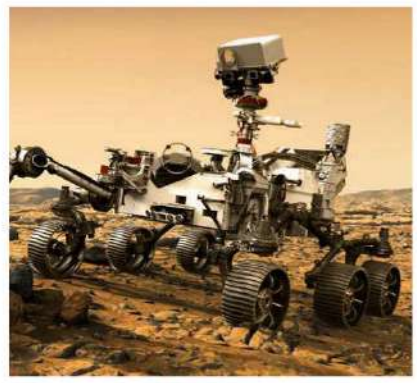
88 NEXT MONTH
A sneak peek at the next issue.

90 POPCORN SCIENCE
Could we become cold, ruthless Cybermen?

58 SUBSCRIBE TODAY!

Save 40% on the shop price when you subscribe to *BBC Science Focus*!

13 DISCOVERIES



Perseverance has discovered the largest cache of organic material ever found on the Red Planet.

36 REALITY CHECK

Don't sneer, national mourning is a fundamental part of human bonding. Here's the neuroscience.

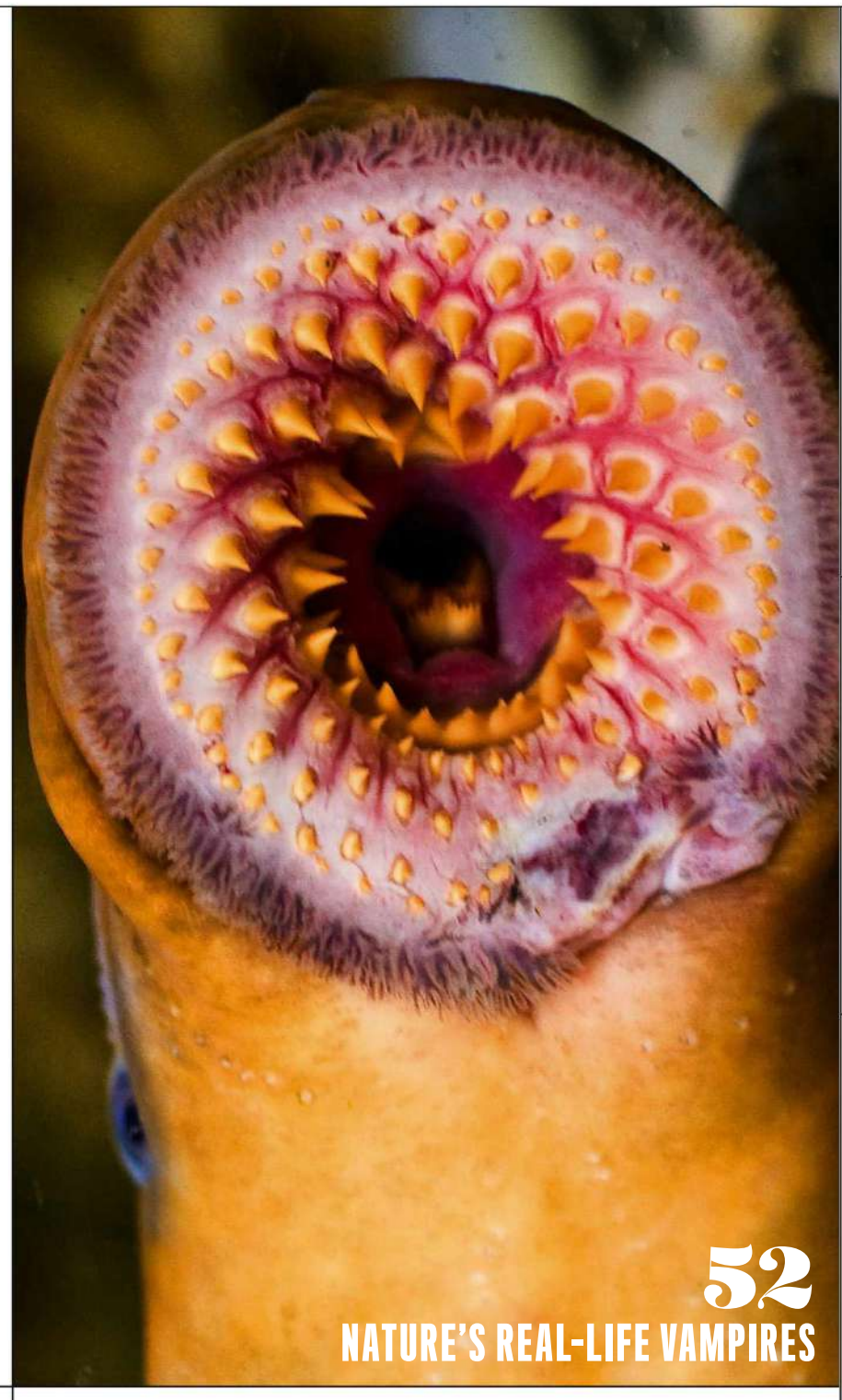
75 Q&A

FEATURES

52 NATURE'S REAL-LIFE VAMPIRES
For Halloween, we take a closer look at some of the animals that quaff blood to survive. Cheers.

60 FIRST CONTACT
We detect an alien message. So what happens next? Here, we find out what the protocol says, and whether we will actually be able to decipher any signals from ET.

68 THE LONELY HEARTS CLUB MAN
A recent YouGov poll concluded that one in five men have no close friends. But why do modern men struggle to maintain their friendships, particularly beyond their 30s? We ask anthropologists and psychologists to tell us more.



52
NATURE'S REAL-LIFE VAMPIRES

48
IDEAS WE LIKE...
Washable headphones that charge in sunlight.

68
PROF ROBIN DUNBAR

"DANCING, SINGING, PLAYING RUGBY OR TENNIS, CLIMBING HILLS – WHEN YOU DO IT WITH OTHER PEOPLE, YOU END UP BONDING"

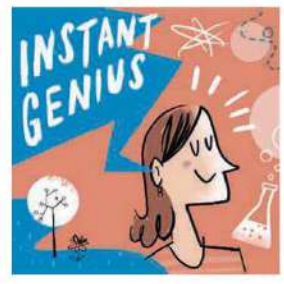
WANT MORE?

Don't forget that *BBC Science Focus* is available on all major digital platforms. We have versions for Android, as well as an iOS app for the iPad and iPhone.

Can't wait until next month to get your fix of science and tech? Our website is packed with news, articles and Q&As to keep your brain satisfied.
sciencefocus.com

INSTANT GENIUS

Our bite-sized masterclass in podcast form. Find it wherever you listen to your podcasts.



LUNCHTIME GENIUS

A DAILY DOSE OF MENTAL REFRESHMENT DELIVERED STRAIGHT TO YOUR INBOX

Sign up to discover the latest news, views and breakthroughs from the *BBC Science Focus* team
www.sciencefocus.com/newsletter

EYE OPENER

Degrees of separation

DENVER, COLORADO, USA

This is what one of the two solar arrays for NASA's Lucy probe looked like during testing, ahead of its launch in October 2021. It's actually similar to what one of the arrays looks like now, after it failed to fully deploy. The circular arrays were designed to open like fans, but one got stuck, reportedly around 10° short of its 360° target.

The arrays will gather solar power for Lucy during its mission to explore the Trojan asteroids, which sit on Jupiter's orbital path and are believed to remnants of the material that formed the outer planets of the Solar System. Lucy's still got a long way to go to reach them (its ETA is August 2027), but, by the time you read this, the probe should have just completed the first of two flybys of Earth it needs to catapult it out to the Trojans.

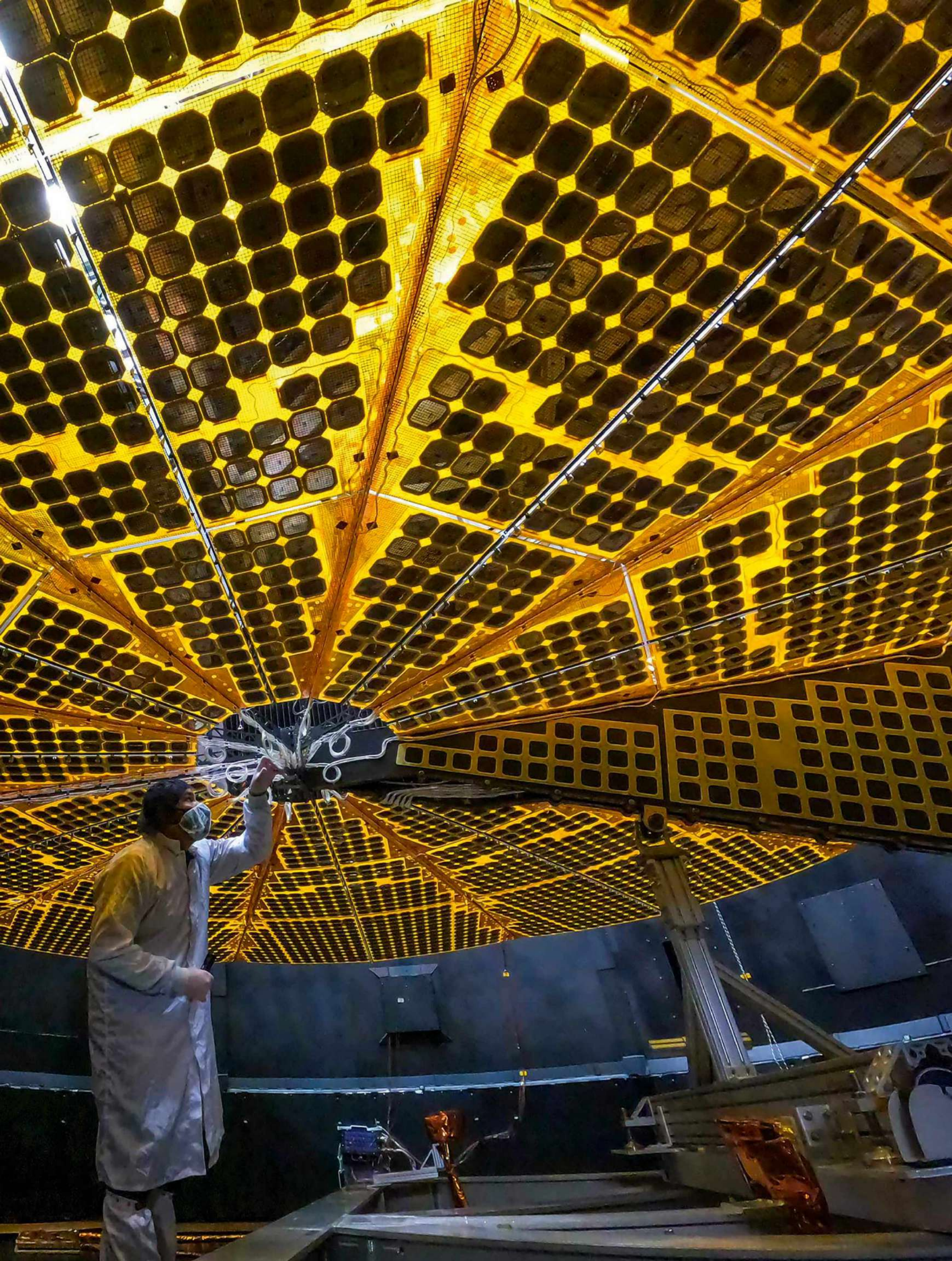
NASA experts have been working to free the stuck array throughout 2022 and, in June, announced they'd made progress. The second array is now said to have reached 357° and should be capable of providing the power Lucy needs to complete its mission.

LOCKHEED MARTIN SPACE/NASA

VISIT US FOR MORE AMAZING IMAGES:

SCIENCEFOCUS

BBCSCIENCEFOCUS



EYE OPENER

Giant's footsteps

DINOSAUR VALLEY STATE PARK, TEXAS, USA

Following a summer of excessive drought conditions, parts of the Paluxy River in the US state of Texas dried up. When the water receded, new dinosaur tracks were revealed on the now-exposed riverbed.

"This area is well known for dinosaur tracks, and the first ones were found around 100 years ago, but this discovery shows that there are a lot more of them out there," says Prof Steve Brusatte, a palaeontologist at the University of Edinburgh.

"These huge prints were made by dinosaurs walking along the shore of an ancient subtropical sea. Many of them were bus-sized, carnivorous theropods that would have been nearly the size of *Tyrannosaurus rex*, which would live in the same area a few tens of millions of years later. These carnivores were the apex predators of their day and, at that time, were the biggest meat-eaters that had ever lived, as far as we know."

COVER IMAGES

VISIT US FOR MORE AMAZING IMAGES:

SCIENCEFOCUS

BBCSCIENCEFOCUS

CONVERSATION

YOUR OPINIONS ON SCIENCE, TECHNOLOGY AND *BBC SCIENCE FOCUS*

reply@sciencefocus.com
BBC Science Focus, Eagle House, Bristol, BS1 4ST
@sciencefocus
www.facebook.com/sciencefocus
@bbcsciencefocus

LETTER OF THE MONTH

Science soothes in difficult times

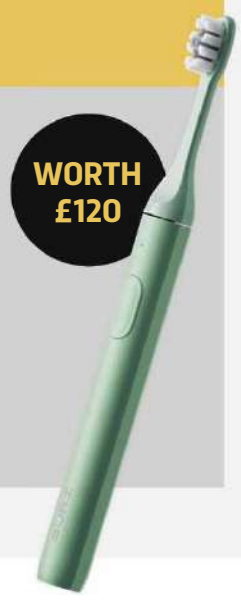
We all heard the devastating news that Queen Elizabeth II passed away a few hours after doctors raised concerns for her health. But it made me think that the royal family wouldn't have been able to rush to be by her side if it wasn't for the progress made possible by science and technology. Imagine if they had to receive the news by post and travel to Balmoral using carriages. But the benefits of such progress are not exclusive to the royal family. Nowadays, I can travel by air from London to Tehran in six hours to be with my family, something I couldn't have done a hundred years ago. It seems science and technology can hold our hands long before we reach our loved ones.

Ghoncheh Azad, London

WRITE IN AND WIN!

The writer of next issue's *Letter Of The Month* wins a **Suri Sustainable Sonic Toothbrush.** Instead of plastic, the replaceable heads on the Suri toothbrush are made from corn starch and castor oil, and Suri will recycle them for free. Inside the aluminium body of the brush is Suri's new MicraSonic magnetic motor, which, despite being one-third the size of standard electric toothbrush motors, can vibrate the head at 33,000 times a minute to give your teeth a superior clean.

trysuri.com



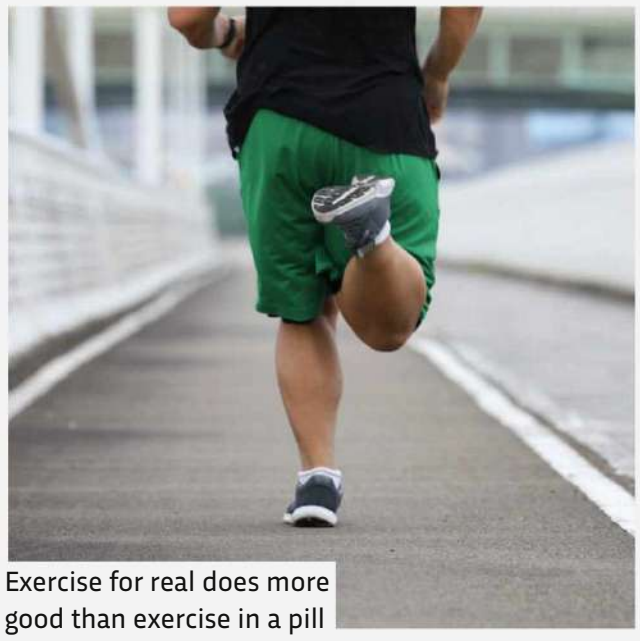
Grateful for fat

As someone who reluctantly took to exercise at 40, and who still carries more fat than he would like, it's interesting to get a fuller picture of what it's doing for me (August, p70). It's nice to know that while I might not have appreciated its efforts, it has continued making them for me during the 15 years I've spent trying to eradicate it. Maybe I'll look more kindly on it in future, although I'm determined to keep exercising. The main reason being the points made in another piece from that issue, regarding the pill that might mimic the effects of exercise (August, p30). Unfortunately, while it seems that effective appetite-suppressants might be possible, they won't offer the cardiovascular or musculoskeletal benefits of exercise, not to mention the positive mental effects – something a pill could never hope to offer. On the plus side, maybe such a pill would allow me to have dark chocolate Hobnobs in the house without being unable to resist them, which would be good for my mental health!

Simon Bartlett, via email

Comic relief

The article by Dr Modgil on the use of music for pain management (September, p28) reminded me of the story of an American



Exercise for real does more good than exercise in a pill

"THE BEST EVIDENCE FOR DARK MATTER COMES FROM COSMIC PHENOMENA OCCURRING ON SCALES MUCH LARGER THAN ANY GALAXY"

DR KATIE MACK, P32

A tree cocooned in caterpillar silk, photographed by John Harrison

called Norman Cousins. He was suffering from a long-term medical condition that caused him considerable pain. He found that reading something amusing, or watching a funny film, could help relieve the pain for hours, without side effects. Cousins went on to write a book, *The Anatomy Of An Illness*, to highlight the effectiveness of humour for pain control. It's lucky that Cousins was able to come to his discovery without needing test animals, since it might have proved difficult to get mice to appreciate a good joke. Still, I suppose he could have shown them a series of Tom and Jerry cartoons.

Peter Davey, Bournemouth

There have been studies on comedy and the perception of pain. One of them showed how humour or comedy therapy can provide significant decreases in the perception of chronic pain and loneliness, as well as increases in happiness and life satisfaction. Perhaps this points to the fact that the arts have much to contribute to our wellbeing.

Dr Radha Modgil, A&E doctor

Wrapped in silk

Seeing the picture of trees cocooned in spider silk (August, p56) reminded me of something I once saw on the Pennine Way: caterpillars had wrapped trees, nearby walls and vegetation in sheets of white gossamer. On closer investigation, we saw scores of them moving across it. Later we met a group of naturalists and described what we'd seen (we couldn't show them the pictures as they were stuck on the film in my camera). But they were unaware of such behaviour in caterpillars. Then, 40 years later, I saw an article with a similar picture in a newspaper, that described the caterpillars responsible as 'bird cherry ermine moths' (*Yponomeuta evonymella*).

John Harrison, Wokingham

GETTY IMAGES X2, JOHN HARRISON, NERISSA ESCANLAR

THE TEAM

EDITORIAL
Editor Daniel Bennett
Managing editor Alice Lipscombe-Southwell
Commissioning editor Jason Goodyer
Staff writers Alex Hughes, Holly Spanner
Editorial assistant Amy Barrett

ART
Art editor Joe Eden
Picture editor James Cutmore

CONTRIBUTORS
Acute Graphics, James Abbott, Claire Asher, Rob Banino, Elena Bansh, Hayley Bennett, Peter Bentley, Brittney G Borowiec, Daniel Bright, Dean Burnett, Daniel Crespo, Stuart Clark, Emma Davies, Kate Darling, Sam Falconer, Sam Freeman, Alastair Gunn, Alice Gregory, Christian Jarrett, Stephen Kelly, Pete Lawrence, Katie Mack, Nish Manek, Adam Mazur, Neil McKim, Radha Modgil, Stephanie Organ, Helen Pilcher, Andy Potts, Jeremy Rossman, Kyle Smart, Ian Taylor, Jocelyn Timperley, Valentin Tkach, Luis Villazon.

ADVERTISING & MARKETING
Business development manager David D'Souza
Newstrade manager Rob Brock
Subscriptions director Jacky Perales-Morris
Direct marketing manager Kellie Lane

MOBILE
Head of apps and digital edition marketing Mark Summerton

INSERTS
Laurence Robertson 00353 876 902208

LICENSING & SYNDICATION
Director of licensing and syndication Tim Hudson
International partners manager Anna Brown

PRODUCTION
Production director Sarah Powell
Production coordinator Lauren Morris
Ad services manager Paul Thornton
Ad designer Julia Young

PUBLISHING
Publisher Andrew Davies
Group managing director Andy Marshall
CEO Tom Bureau

BBC STUDIOS, UK PUBLISHING
Chair, editorial review boards Nicholas Brett
Managing director, consumer products and licensing Stephen Davies
Director, magazines and consumer products Mandy Thwaites
Compliance manager Cameron McEwan
UK publishing coordinator Eva Abramik
Contact UK.Publishing@bbc.com
www.bbcstudios.com

EDITORIAL COMPLAINTS
editorialcomplaints@immediate.co.uk

ANNUAL SUBSCRIPTION RATES (INC P&P):
UK/BFPO £77; Europe & Eire £92.54;
Rest of World £102.90.

Audit Bureau of Circulations
50,142 (combined, Jan-Dec 2021)

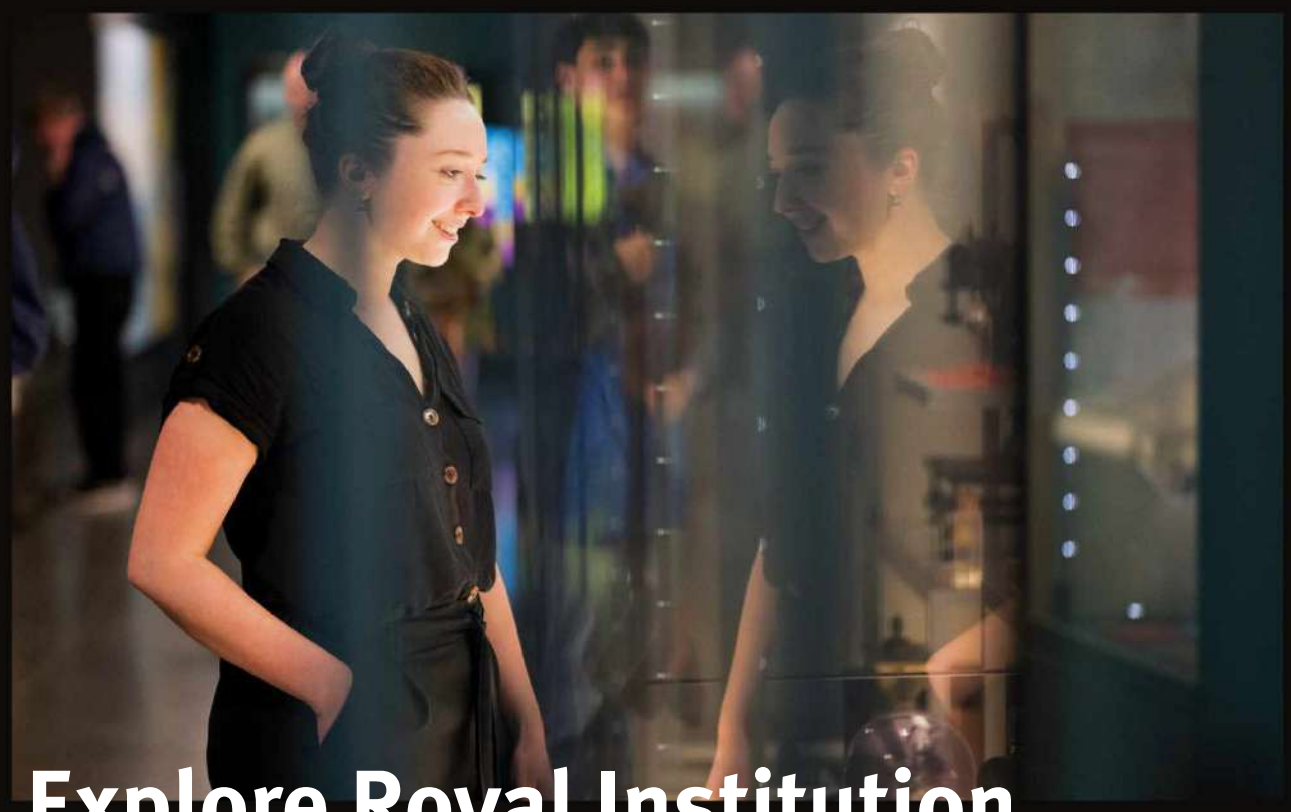
BBC Science Focus Magazine is published by Our Media Ltd (an Immediate Group Company), under licence from BBC Studios who help fund new BBC programmes.

© Our Media Ltd 2022. All rights reserved. Printed by William Gibbons Ltd.

Our Media Ltd accepts no responsibility in respect of products or services obtained through advertisements carried in this magazine.

recycle
When you have finished with this magazine please recycle it.

The Royal Institution
Science Lives Here



Science talks

Free museum

Digital content

Workshops and courses

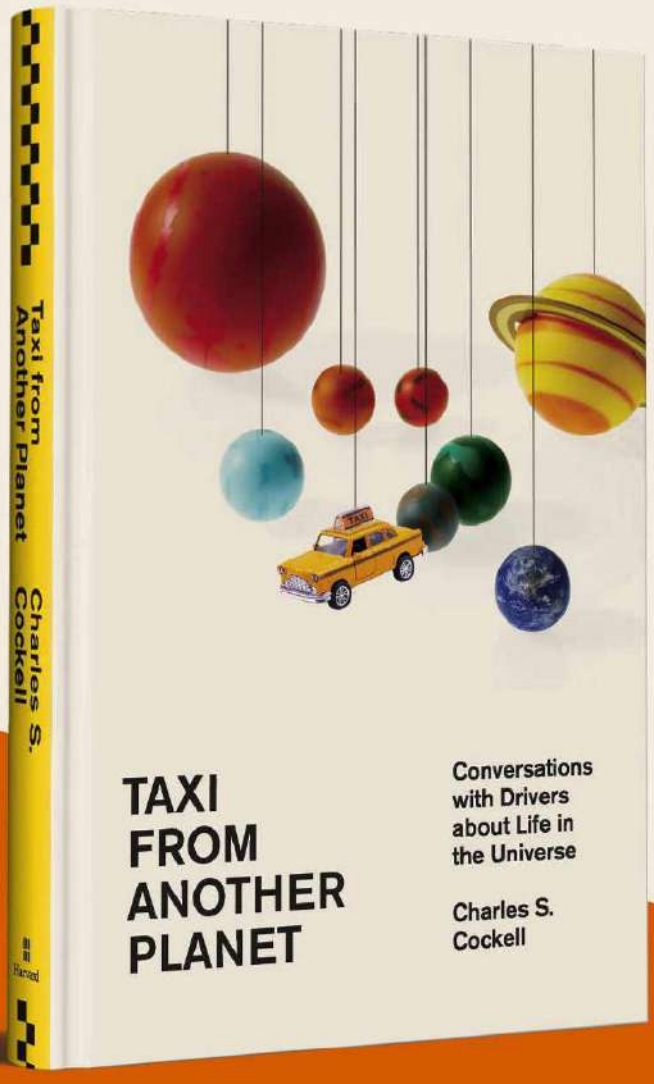
Get involved today

Sign up to our newsletter to see what's on at the Ri and discover great science content. Get exclusive discounts and enter the 2022 CHRISTMAS LECTURES ballot - exclusively open for Ri Members now!

Explore Royal Institution science and be inspired

@Ri_Science @RoyalInstitution

rigb.org/sign-up


Taxi from Another Planet
Charles S. Cockell
TAXI FROM ANOTHER PLANET
Conversations with Drivers about Life in the Universe
Charles S. Cockell

"This is a joy to read."

–Publishers Weekly

"*Taxi from Another Planet* conveys an array of ideas–all fascinating, and some profound–with a light touch and utter clarity. Accessible to anyone curious about the cosmos."

–Martin Rees, coauthor of *The End of Astronauts*

Harvard University Press | hup.harvard.edu

DISCOVERIES

“Hopefully it will be a success, but it might be a very successful failure”
Dr Tim Gregory **p24**

MARS

LIFE ON MARS?

Organic compounds discovered by Perseverance rover **p14**

HEALTH

TAKE FIVE

Microbreaks could help prevent workplace burnout **p16**

BIOLOGY

GENES FROM LATRINES

Parasite found in Viking poo has its genome mapped **p18**

SOLAR SYSTEM

RING THE CHANGES

New research suggests Saturn’s rings were formed by a moon **p20**

ASTRONOMY

STARRY SPIDER

James Webb Space Telescope images the Tarantula Nebula **p20**

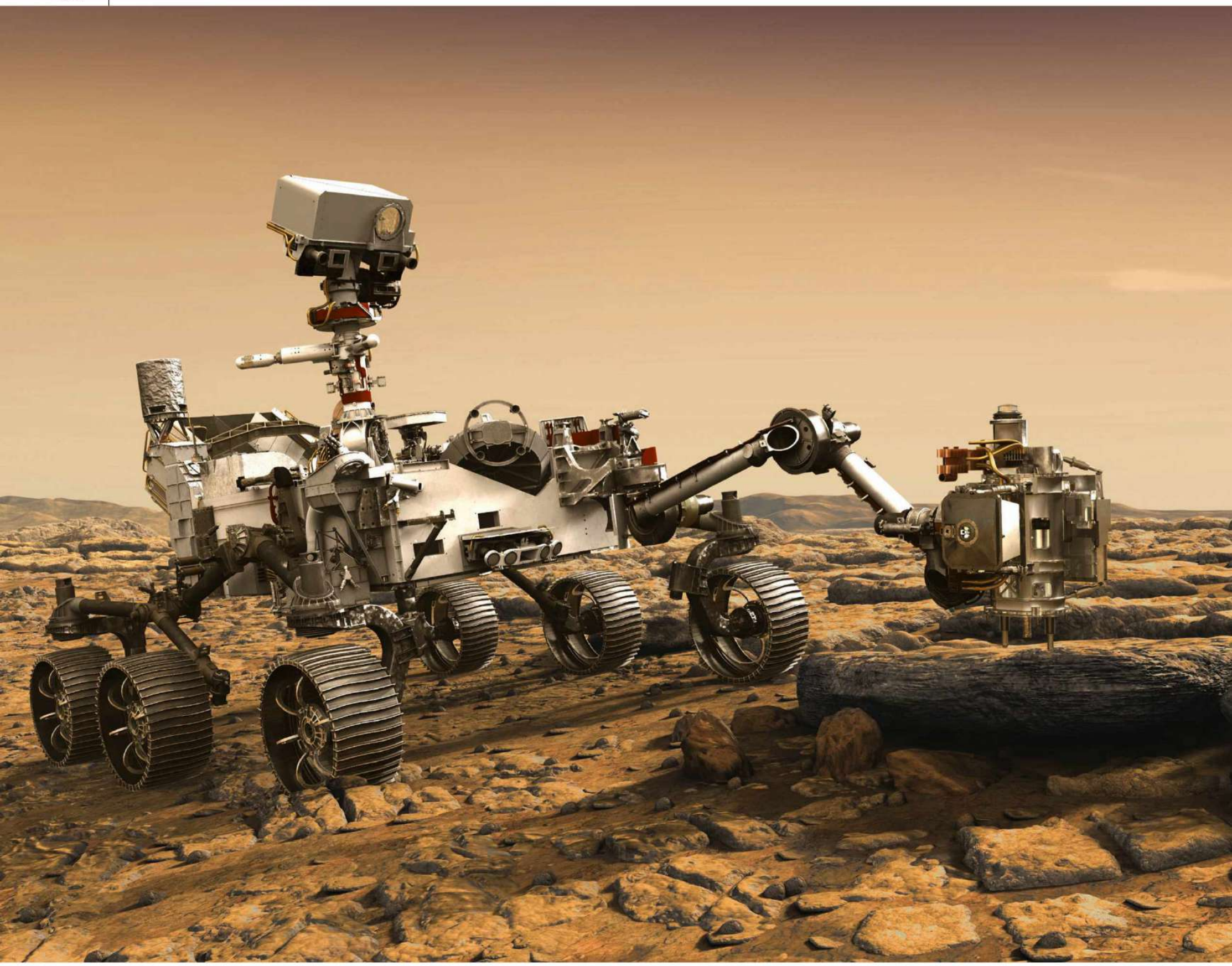
SPACE

SMASHING ASTEROIDS

How will the DART mission deflect a space rock? **p24**

Fossilised whipworm eggs had their genome compared to modern samples

ALAMY



MARS

PERSEVERANCE ROVER DISCOVERS MORE ORGANIC MATERIAL ON MARS THAN EVER BEFORE

The rover collected samples from an area where scientists think life could have thrived on ancient Mars

ABOVE
Perseverance is hunting for signs of microbial life, and stashing samples to return to Earth for analysis

As part of its continuing exploration of an ancient Martian riverbed, NASA's Perseverance rover has collected some of the most promising samples yet in its ongoing search for signs of life on the Red Planet. Among them are several samples of sandstone and mudstone, collected from a one-metre-wide rocky outcrop named Wildcat Ridge that is packed with organic compounds – chemicals essential for life on Earth.

Perseverance has been trundling around an area known as the Jezero Crater since September 2021 and has so far collected 12 samples of rock.

All of the samples it collects over its two-year mission are scheduled to be brought back to Earth for analysis in 2033 as part of the Mars Sample Return mission.

The Jezero Crater lies just north of the Martian equator. It is 45km wide and home to an ancient

MISSION TIMELINE

JULY 2020
Perseverance launches from Cape Canaveral, Florida, on an Atlas V rocket.

FEBRUARY 2021
Perseverance safely touches down on Mars, in the Jezero Crater.

JUNE 2021
Perseverance begins collecting data as part of its first science campaign.

AUGUST 2021
Perseverance successfully collects its first sample of Martian rock.

2027
Mars Sample Return orbiter is scheduled to launch from Earth.

2028
Mars Sample Return lander is scheduled to launch from Earth.

2033
Mars samples due to arrive back on Earth for further study and analysis.

"The organic matter was found in sedimentary rock – known for preserving fossils of ancient life here on Earth"

fan-shaped delta that formed about 3.5 billion years ago when rivers spilled over the crater walls and created a lake.

"We picked the Jezero Crater for Perseverance to explore because we thought it had the best chance of providing scientifically excellent samples – and now we know we sent the rover to the right location," said Dr Thomas Zurbuchen, NASA's associate administrator for science in Washington.

A preliminary analysis of the Wildcat Ridge samples was carried out by an instrument onboard Perseverance called Scanning Habitable Environments with Raman and Luminescence for Organics and Chemicals, or SHERLOC.

Although evidence of organic matter has been found on Mars before, both by Perseverance and its predecessor Curiosity, SHERLOC's analysis indicates that the Wildcat Ridge samples contain the largest number of organic compounds of any collected to date.

ABOVE The remains of an ancient river delta in Mars's Jezero Crater

ABOVE RIGHT Perseverance project scientist Prof Ken Farley

"In the distant past, the sand, mud and salts that now make up the Wildcat Ridge sample were deposited under conditions where life could potentially have thrived," said Perseverance project scientist Prof Ken Farley of Caltech in Pasadena, California.

"The fact the organic matter was found in such a sedimentary rock – known for preserving fossils of ancient life here on Earth – is important.

"However, as capable as our instruments aboard Perseverance are, further conclusions regarding what is contained in the Wildcat Ridge sample will have to wait until it's returned to Earth for in-depth study as part of the agency's Mars Sample Return campaign."

NASA/JPL-CALTECH X2, CALTECH

HEALTH

MICROBREAKS MAY HELP TO PREVENT WORKPLACE BURNOUT

Walking and stretching are particularly effective ways to use your break

Short conversations that aren't work-related – so-called 'water cooler moments' – can be a welcome break from everyday office life. Now, a new meta-analysis published in the journal *PLOS One*, has pulled together evidence to look at whether short microbreaks could help with workplace wellbeing.

A team of scientists at Romania's West University of Timișoara (WUT) examined data from 22 studies from the past 30 years to find out whether the type of activity a person engages in during a 10-minute microbreak from tasks can affect their overall mood.

Tasks varied between the featured experiments, and included work simulations, work-related assignments or cognitive tests. After the tasks, the participants took a 10-minute microbreak, where they could enjoy activities like stretching, walking, watching videos, or just relaxing. The microbreak sometimes involved things like helping a colleague, or some other work-related activity.

The researchers discovered that, when it came to assessing whether the break had a positive or negative effect on an individual's mood, the activity engaged in during the break was an important factor.

Participants found the breaks where they carried out exercise to be particularly helpful. The authors noted that "physical activities such as stretching and exercise were associated with increased positive emotions and decreased fatigue".

But if the microbreak activity involved helping a colleague or something else work-related, it led to negative emotions, decreased wellbeing and worse sleep quality.

Overall, the data appears to support the role of microbreaks for boosting wellbeing of workers and reducing fatigue, but there was insufficient evidence to suggest that microbreaks improve job performance.

With today's employees experiencing burnout, long hours and ever-increasing workloads, microbreaks could offer a way to improve happiness. So go on, get that kettle on!

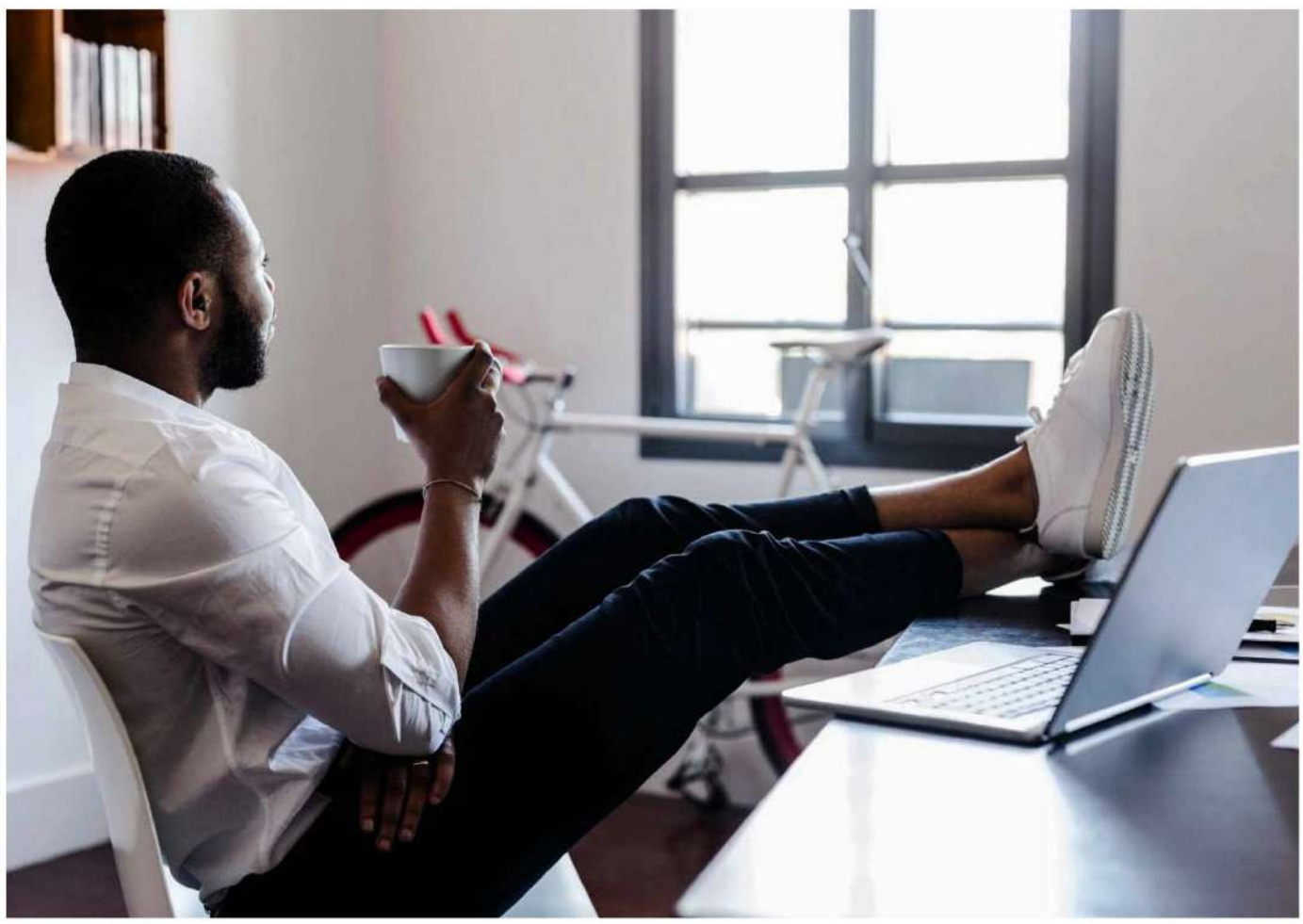
When taking a 10-minute break from the daily grind, try not to get roped into work-related tasks. Instead, relax, or do some gentle exercise

WHAT IS BURNOUT?

The World Health Organization (WHO) defines burnout as a syndrome resulting from chronic workplace stress that has not been successfully managed. It results in three effects:

- Feelings of depletion or exhaustion
- Increased mental distance from one's job, or feelings of negativism or cynicism related to one's job
- Reduced professional efficacy

It should not be applied to other, non-work-related aspects of life, and is not classified as a medical condition, the WHO says.

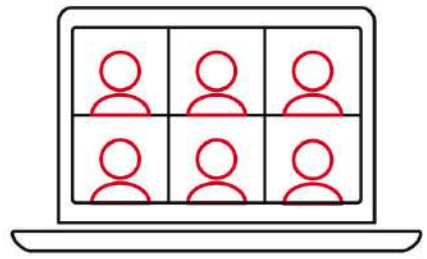


GETTY IMAGES X2

SCREEN USE: IN NUMBERS

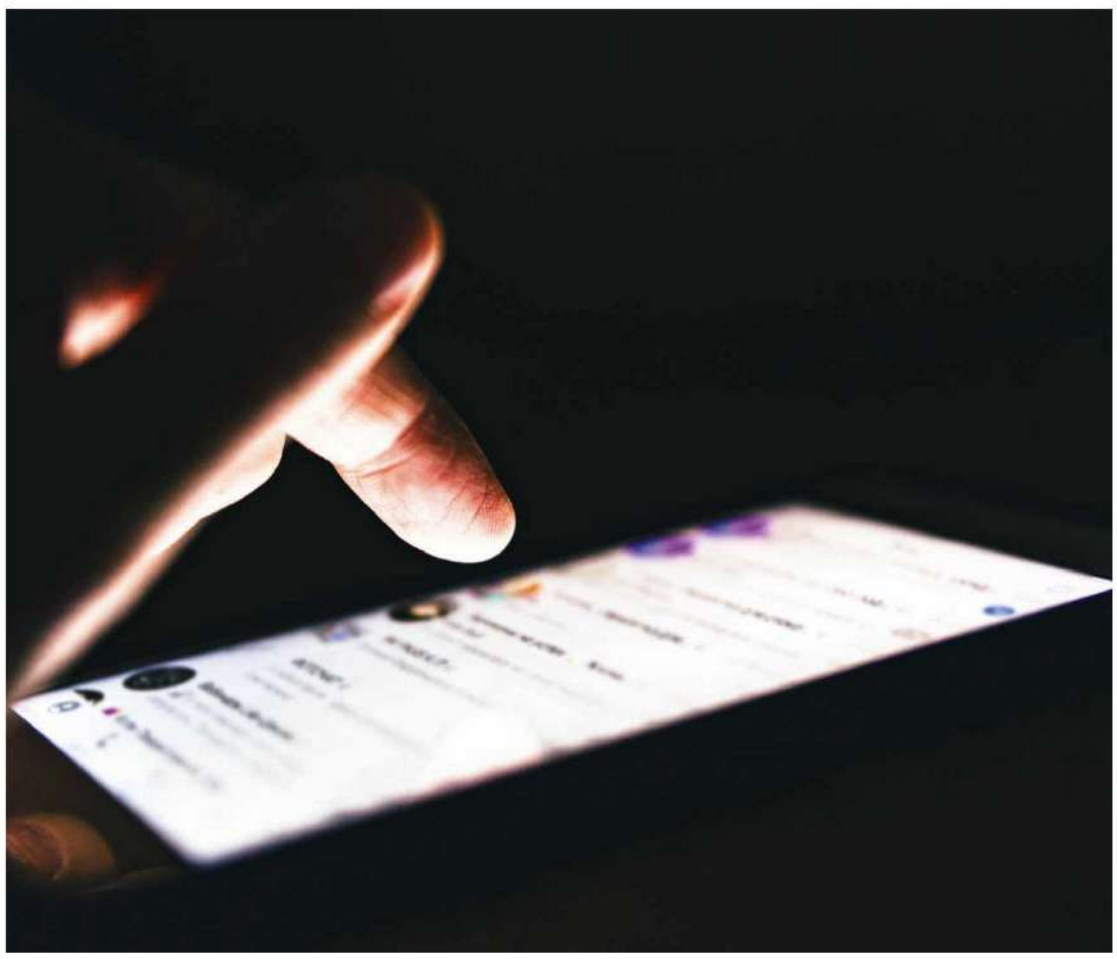
In April 2022, researchers at the University of Leeds surveyed 500 UK adults about their daily screen use. Here's what they found.

One-quarter of those surveyed looked at screens for upwards of 14 hours a day.



One-half said their screen use had increased during the lockdowns due to the coronavirus pandemic.

Four in 10 said they'd experienced physical side effects, including eye strain, headaches and fatigue.



LEFT Blue light is emitted by LEDs, which are present in many modern gadgets, such as smartphones, laptop screens and flatscreen TVs

BIOLOGY

YOUR PHONE SCREEN COULD BE AGEING YOU

Study on fruit flies suggests blue light could have a significant effect on cell function

We are often told that too much time spent on smartphones isn't good for us, and now a new study suggests that it could even be increasing the speed at which we age.

Researchers from Oregon State University used fruit flies to test the effects of blue light. They found evidence that our basic cellular functions could be impacted by this light that is emitted from smartphones and other devices.

"Excessive exposure to blue light from everyday devices, such as TVs, laptops, and phones, may have detrimental effects on a wide range of cells in our body, from skin and fat cells, to sensory neurons," said senior author Prof Jadwiga Giebultowicz, of Oregon State University.

"We are the first to show that the levels of specific metabolites – chemicals that are essential for cells to function correctly – are altered in fruit flies exposed to blue light. Our study suggests that avoidance of excessive blue light exposure may be a good anti-ageing strategy."

In their research, the team found that fruit flies exposed to blue light activated their stress protective genes. The fruit flies that were kept in constant darkness were found to live longer.

"To understand why high-energy blue light is responsible for accelerating ageing in fruit flies, we compared the levels of metabolites in flies exposed to blue light for two weeks to those kept in complete darkness," said Giebultowicz.

Metabolites are substances that are made or used when the body is breaking things down, including drugs, food, chemicals or anything you put in your body. The researchers discovered that blue light exposure caused large differences in the levels of metabolites in the cells of the fly heads. In particular, they found that levels of the metabolite succinate increased, but glutamate lowered.

"Succinate is essential for producing the fuel for the function and growth of each cell. High levels of succinate after exposure to blue light can be compared to gas being in the pump but not getting into the car," said Giebultowicz.

"Another troubling discovery was that molecules responsible for communication between neurons, such as glutamate, are at the lower level after blue light exposure."

The results of this study could suggest that cells perform at suboptimal levels with blue light exposure, causing their early death. This could then lead to accelerated ageing if subjects are exposed to too much blue light.

While the results from the study are an indication of how blue light could affect humans, it isn't a perfect comparison and the researchers are now hoping to perform further research on human cells.

BIOLOGY

PARASITE FROM FOSSILISED VIKING POO HAS GENOME MAPPED

Though now rare in industrialised countries, the human whipworm still infects around 500 million people worldwide and can cause serious illness in the weak or malnourished

By extracting fossilised eggs from samples of faeces collected from Viking settlements across Denmark, researchers from the University of Copenhagen have mapped the genome of the whipworm – a parasite that has infected humans for tens of thousands of years.

While the human whipworm, *Trichuris trichiura*, is now rarely found in developed countries, it is thought to infect more than 500 million people in developing countries.

The team sequenced the genomes of the eggs and compared them to the genomes of contemporary samples harvested from people across the world who were infected with whipworms.

The findings from the study have given the scientists a deeper understanding of the parasite's evolution and its interaction with humans. This knowledge can now be used to create new drugs to treat infection and prevent the parasite's future spread, the researchers say.

"In people who are malnourished or have impaired immune systems, whipworm can lead to serious illness," said lead researcher Prof Christian Kapel, of the University of Copenhagen.

"Our mapping of the whipworm and its genetic development makes it easier to design more effective anti-worm drugs that can be used to prevent the spread of this parasite in the world's poorest regions."

Whipworms live in the intestines of their human hosts and can grow to seven centimetres in length. Over a lifetime that spans several months, they continuously lay microscopic eggs that later exit the host's body in faeces. These eggs can then spread to drinking water or food where they can be unknowingly consumed by another human host, beginning the entire cycle once more.

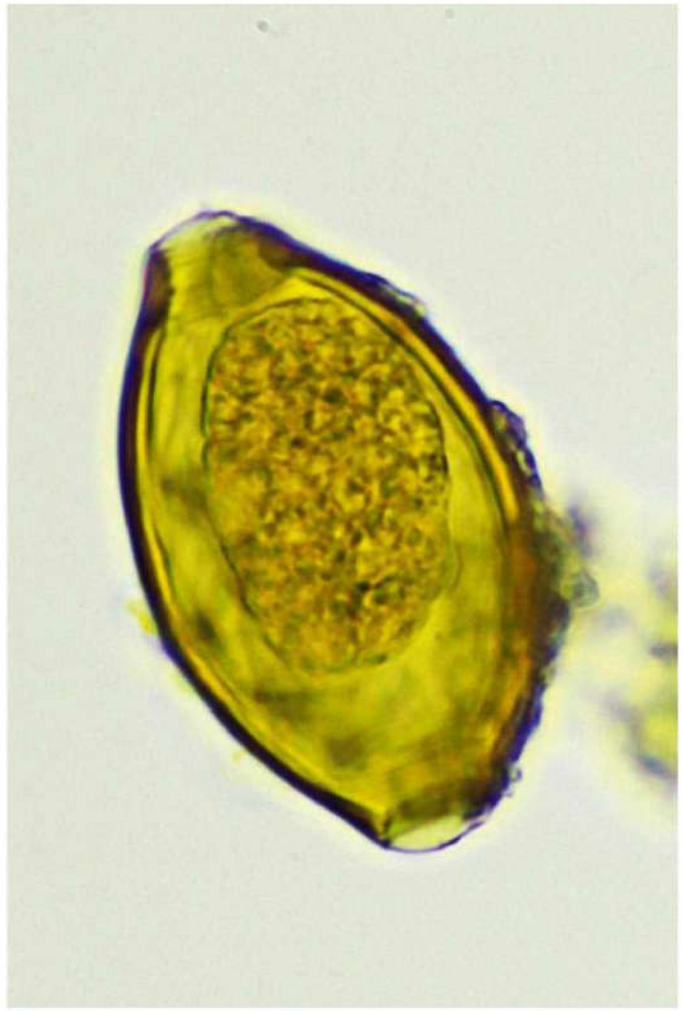
"During the Viking Age and well into the Middle Ages, one didn't have very sanitary conditions or well-separated cooking and toilet facilities. This allowed the whipworm far better opportunities to spread," said Kapel.

"Today, it is very rare in the industrialised parts of the world. Unfortunately, favourable conditions for spreading still exist in less developed regions of the world."

The researchers sieved the eggs from stool samples taken from Viking settlements in Viborg and Copenhagen. They found that the DNA inside the eggs was incredibly well preserved, even though some of the eggs were 5,000 years old. This is thanks to the chitin, a tough, naturally occurring polymer also found in the exoskeletons of crustaceans and insects, that makes up the eggs' hard outer capsules.

"Unsurprisingly, we can see that the whipworm appears to have spread from Africa to the rest of the world along with humans about 55,000 years ago, following the so-called 'out of Africa' hypothesis on human migration," said Kapel.

MAIN IMAGE The stool samples were extracted from latrines of Viking settlements

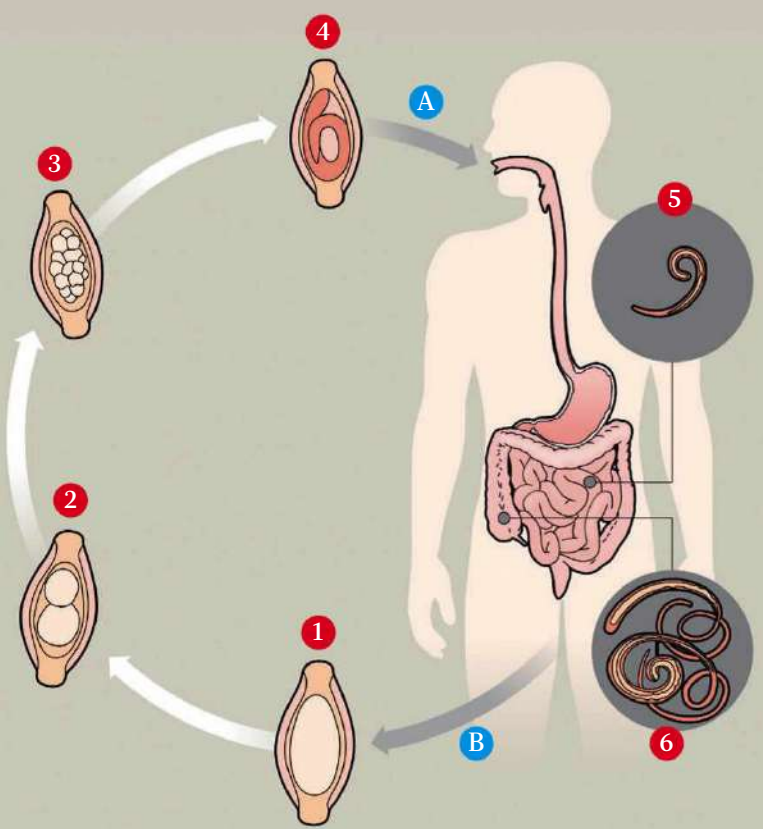


BELOW Whipworm eggs, seen here magnified by 400x, have a tough outer covering, meaning they can still be intact after thousands of years

"Our mapping of the whipworm and its genetic development makes it easier to design more effective anti-worm drugs"

GETTY IMAGES X2 ILLUSTRATION: ACUTE GRAPHICS

THE LIFE CYCLE OF A WHIPWORM



A INFECTIVE STAGE B DIAGNOSTIC STAGE

1 Immature eggs pass out of the body in faeces 2 Once in the soil, the eggs starts to develop 3 The eggs continue developing over 14-21 days 4 Once the eggs are 'embryonated' (they have fully developed larvae inside), they can infect humans 5 After ingestion by a human, the eggs hatch in the small intestine and the larvae emerge 6 The larvae move into the large intestine and start developing into adults. The adults attach themselves to the wall of the intestine, and the females shed between 3,000 and 20,000 eggs per day

HEALTH

AIR POLLUTION COULD TRIGGER LUNG CANCER IN NON-SMOKERS

Research into the dangerous effects of air pollution could lead to approaches to lung cancer prevention

Scientists have discovered a new mechanism through which tiny pollutant particles in the air may trigger lung cancer, even in people who have never smoked. This identification could now be used to develop new prevention measures or even therapies for lung cancer. The particles, which are typically found in vehicle emissions and fossil fuel smoke, are associated with the most common form of lung cancer, accounting for over 250,000 lung cancer deaths each year worldwide.

The research was funded by Cancer Research UK and was carried out by scientists of the Francis Crick Institute and the University College London.

"The same particles in the air that derive from the combustion of fossil fuels, exacerbating climate change, are directly impacting human health via an important and previously overlooked cancer-causing mechanism in lung cells," said Prof Charles Swanton, chief clinician of Cancer Research UK.

"The risk of lung cancer from air pollution is lower than from smoking, but we have no control over what we all breathe. Globally, more people are exposed to unsafe levels of air pollution than to toxic chemicals in cigarette smoke, and these new data sets link the importance of addressing climate health to improving human health."

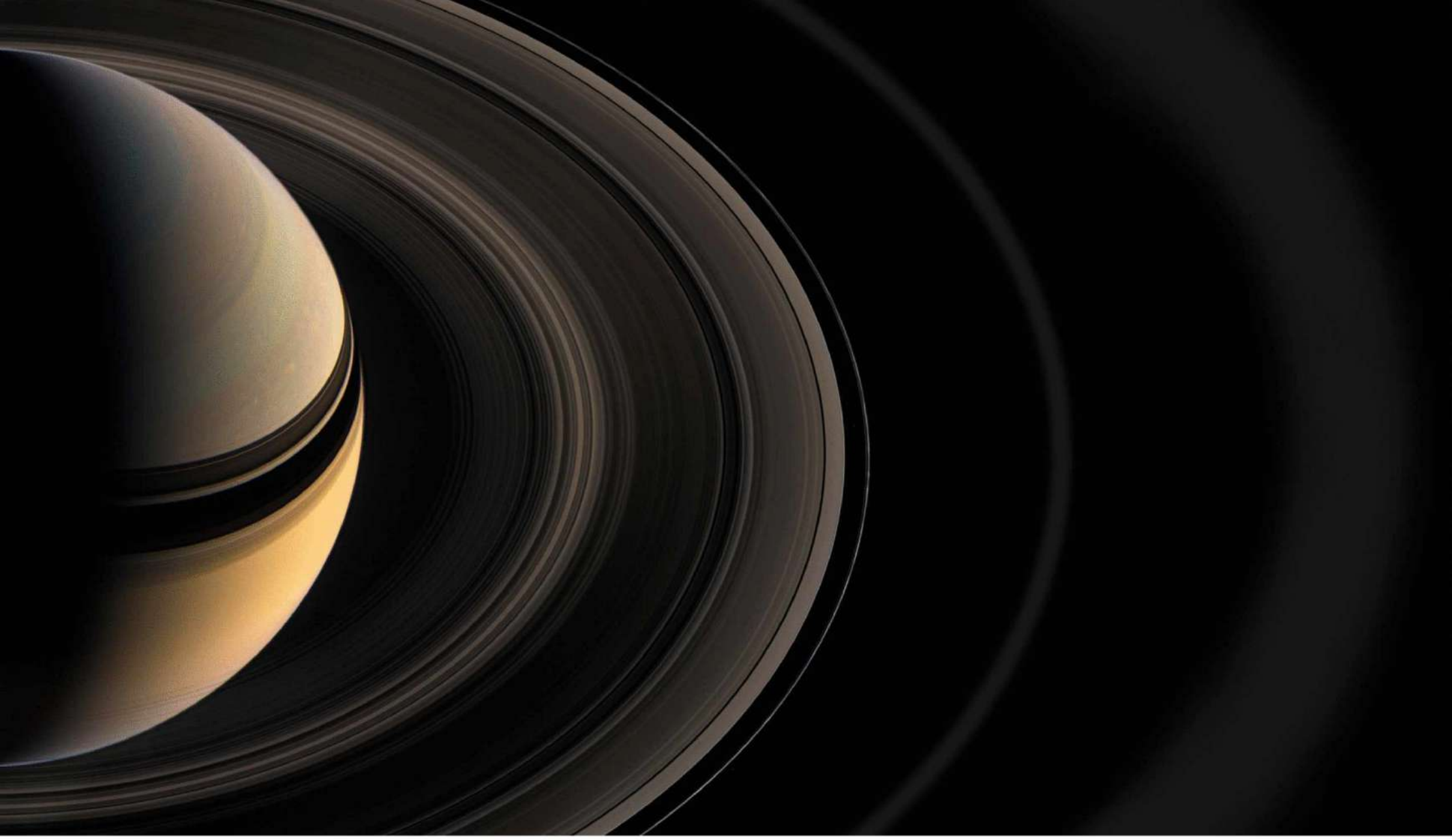
These new findings come from both human and lab research on mutations in a gene known as EGFR. These mutations are seen in about half of people with lung cancer who have never smoked. Exposure to increasing concentrations of airborne particles was linked to an bigger risk of EGFR mutations and lung cancer.

In another set of experiments, the Francis Crick team took small samples of normal lung tissue. They found mutations of EGFR and another gene called KRAS, in 18 per cent and 33 per cent of the samples.

"We found that driver mutations in EGFR and KRAS genes, commonly found in lung cancers, are actually present in normal lung tissue and are a likely consequence of ageing," said Swanton.

"However, when lung cells with these mutations were exposed to air pollutants, we saw more cancers and these occurred more quickly than when lung cells with these mutations were not exposed to pollutants."

This suggests that air pollution promotes the initiation of lung cancer in cells that already have particular genetic mutations. The next step for researchers will be to discover why some lung cells with mutations become cancerous when exposed to pollutants while others don't appear to.



SOLAR SYSTEM

SATURN'S ICONIC RINGS MAY HAVE BEEN FORMED BY ANCIENT MOON

Around 160 million years ago, the shattering apart of a moon named Chrysalis may have caused Saturn to tilt and created its signature icy rings

Saturn's iconic tilt and rings may all be down to an ancient moon

Thanks to its trademark disc of icy rings, Saturn is one of the most recognisable planets in the Solar System. But exactly how these distinctive rings formed has remained something of a mystery.

Now, a computer-modelling study carried out by researchers at MIT has suggested that the gas giant's rings, and the nearly 27° tilt at which it moves around the Sun, might be due to an ancient moon careering out of orbit, clipping its host planet and being smashed into hundreds of pieces.

The team made the discovery by using gravitational data collected by NASA's Cassini spacecraft, which orbited Saturn from 2004 to 2017. After running several computer models designed to emulate the orbits of Saturn and its satellites back through time, the researchers determined that billions of years ago, Saturn had at least one more moon, which they have named Chrysalis.

Through gravitational interactions with Chrysalis, Saturn kept its tilt in sync with Neptune. However, around 160 million years ago, Chrysalis became unstable, ventured too close to Saturn and subsequently pulled apart.

The loss of this additional moon was enough to push Saturn out of sync with Neptune, leaving it with its current tilt. Moreover, some fragments of Chrysalis's shattered body may have remained in orbit and eventually broken down to form the planet's signature rings.

The researchers estimate that Chrysalis would have been around 1,500km across – roughly the same size as Iapetus, Saturn's third-largest moon.

"Just like a butterfly's chrysalis, this satellite was long dormant and suddenly became active, and the rings emerged," said Jack Wisdom, professor of planetary sciences at MIT and lead author of the new study.

"It's a pretty good story, but like any other result, it will have to be examined by others. But it seems that this lost satellite was just a chrysalis, waiting to have its instability."

LUNAR LINE-UP

Just 53 of Saturn's 82 moons have been named. Here are two of the most important...

Titan is the largest of Saturn's moons. At 5,150km in diameter it is larger than Mercury, the Solar System's smallest planet.

Enceladus is Saturn's sixth-largest moon. It is of huge scientific interest as it is thought to have liquid oceans flowing beneath its frozen outer shell. This makes it one of the prime targets in the search for biological life in the Solar System.

NASA/JPL-CALTECH X3, JULIUS CSOTONYI/SMITHSONIAN INSTITUTION

PALAEONTOLOGY

REPTILE THAT LIVED AMONG THE DINOSAURS DISCOVERED

This lizard-like animal belongs to the same ancient lineage as New Zealand's living tuatara

The well-preserved fossil of an extinct species of lizard-like reptile has been discovered, shedding light on the evolution of the tuatara – the last living member of this once-diverse group of reptiles.

The fossil was discovered by a team of scientists from the National Museum of Natural History, University College London and the Natural History Museum. They found the new species at a site in Wyoming's Morrison Formation and have named it *Opisthiamimus gregori*. It inhabited Jurassic North America around 150 million years ago, and lived among dinosaurs.

The reptile would have been about 15 centimetres long from nose to tail, and likely survived on a diet of insects and other small invertebrates.

"What's important about the tuatara is that it represents this enormous evolutionary story that we are lucky enough to catch in what is likely its closing act," said Matthew Carrano, one of the authors of the study and the curator of dinosaurs at the National Museum of Natural History.

"Even though it looks like a relatively simple lizard, it embodies an entire evolutionary epic going back more than 200 million years."

After the team had freed as much of the fossil from the rock as possible without damaging it, they scanned it with high-resolution computerised X-ray tomography to make a 3D representation of the fossil. They then used software to painstakingly make a nearly complete 3D reconstruction, recreating bones that were crushed or damaged. They even managed to make a clear version of the skull.

Further study of the specimens found in Wyoming could help reveal why this animal's order of reptiles dwindled. The order, Rhynchocephalia, once contained a diverse array of species, but New Zealand's tuataras are the only surviving members.

Rhynchocephalians diverged from lizards roughly 230 million years ago. Rhynchocephalians were found around the world and came in a range of different shapes and sizes. However, for unknown reasons, they all but disappeared as lizard and snakes became more common.

The fossil has now been added to a museum collection where it will remain for additional study. Researchers hope to be able to one day understand why the tuatara is the last remaining rhynchocephalian.

"These animals may have disappeared partly because of competition from lizards, but perhaps also due to global shifts in climate and changing habitats," Carrano said.

"It's fascinating when you have the dominance of one group giving way to another group over evolutionary time, and we still need more evidence to explain exactly what happened, but fossils like this one are how we will put it together."

Artist's impression of the newly discovered reptile species, chomping on a water bug

ASTRONOMY

TARANTULA NEBULA PHOTOGRAPHED IN UNPRECEDENTED DETAIL

Newly released mosaic from the James Webb Space Telescope peers through the cosmic dust to reveal never-before-seen young stars

Although the wispy swirls of clouds give a sense of serenity, the Tarantula Nebula is actually one of the largest and most violent star-forming regions in our Local Group, which is the collection of galaxies in our cosmic neighbourhood.

The Tarantula Nebula is home to some of the hottest and most massive stars known to astronomers, and in the centre, sparkling blue with

NASA/ESA/CSA/JAMES WEBB SPACE TELESCOPE

massive young stars, is the star cluster R136.

"R136 far exceeds anything in our own Milky Way. It contains almost half a million solar masses [one solar mass = the mass of our Sun]," said Prof Mark McCaughrean, from the European Space Agency.

"It's possible this region is a proto-globular cluster, and its huge cumulative luminosity is what lights up the Tarantula Nebula."

Blistering radiation has blown away the dusty cocoons that once surrounded these young stars. Left behind is only the densest material, sculpted into pillars.

This image, captured with JWST's Near-Infrared Camera (NIRCam), is 340 light-years across, although the nebula's total width exceeds 1,000 light-years.

"The JWST image of the Tarantula Nebula was created using mosaics made through four separate infrared filters," said McCaughrean.

The Tarantula Nebula is of special interest as it has a similar chemical composition to the gigantic star-forming regions known to exist when the Universe was only a few billion years old. Astronomers hope that the crisp images of the nebula produced by NIRCam will help them shed further light on the process of star formation.

HORIZONS

SPACE

HOW NASA DEFLECTED AN ASTEROID BY CRASHING A SPACECRAFT INTO IT

NASA's DART spacecraft made impact with its asteroid target on 27 September. **Dr Tim Gregory** tells us about this first-of-its-kind mission

WHAT IS THE DART MISSION?

It stands for the Double Asteroid Redirection Test. It's essentially a big science experiment to see if crashing a spacecraft into an asteroid is a good way to change its orbit around the Sun and potentially deflect an Earth-crossing asteroid away, should that happen in the future… or rather *when* that happens.

TELL US ABOUT THE SPACECRAFT.

DART is quite a hefty spacecraft. It weighs more than half a tonne, at 610 kilograms. One of my favourite things about this mission is that onboard is a CubeSat [LICIACube, or Light Italian CubeSat for Imaging Asteroids]. CubeSats are little, miniature satellites about the size of a champagne bottle. This particular CubeSat is Italian in origin and it's got a camera.

WHY WAS THE DIDYMOS BINARY ASTEROID SYSTEM SELECTED AS THE TARGET FOR THE MISSION?

The double asteroid is a cool little system. Much like the Earth has a celestial companion with the Moon, some asteroids have celestial companions, too. We call them binary asteroids. The target is made up of two individual objects: Didymos A, which is about 780 metres across, that's roughly seven football pitches; and its smaller companion Dimorphos, which is 160 metres across. The DART mission targeted the smaller of the two, Dimorphos.

It's important to stress that this particular asteroid system doesn't pose a threat to the Earth. It was merely chosen as a target based on its orbit around the Sun. It's got a very well-determined orbit and we will be able to track the new orbit to see if it's changed.

One of the really mind-blowing things about these asteroids is that we don't actually know a lot about them, other than their orbital parameters. We don't know what they look like. We don't know exactly what they're made of. And that's actually true, for basically every single asteroid in the Solar System.

HOW BIG WOULD AN ASTEROID HAVE TO BE TO DO SERIOUS DAMAGE TO THE EARTH?

An asteroid with a diameter of 300 metres, so about the size of the Eiffel Tower, strikes the Earth approximately every 80,000 years, and that releases the same amount of energy as 50 hydrogen bombs being detonated simultaneously.

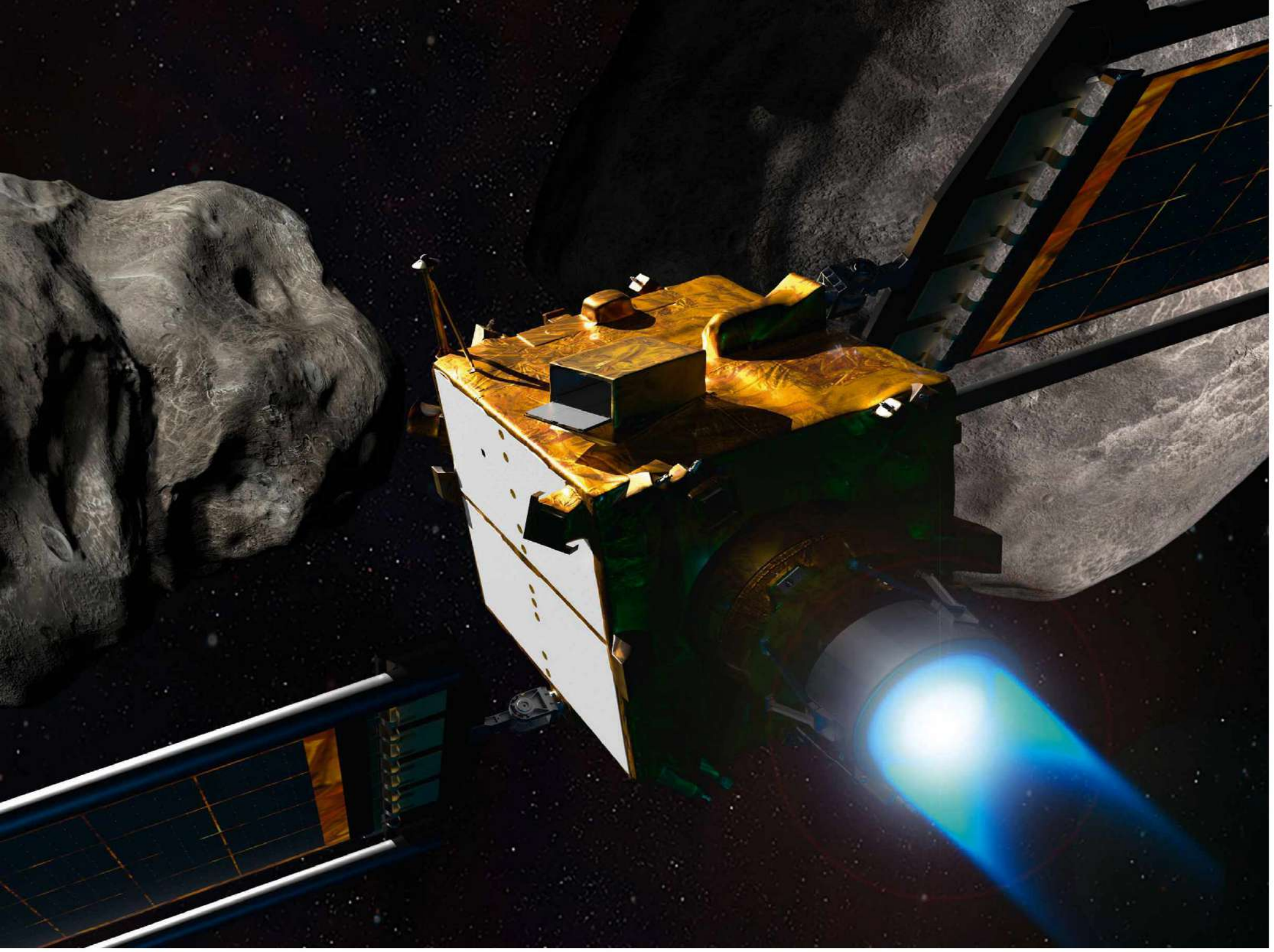
There are around 900 potentially hazardous asteroids that are more than one kilometre across. If one of those hit our planet, it would be the same as almost 2,000 hydrogen bombs' worth of energy. On a local scale, that would be devastating. It's worth noting as well that the dinosaurs went extinct when an asteroid hit the Earth 66 million years ago. But that was a pretty big asteroid that was about 20 kilometres across.

WHY IS THIS METHOD OF DEFLECTION CALLED 'KINETIC IMPACT'?

Kinetic impact is essentially what it says on the tin. It is slamming a spacecraft into an asteroid to ever-so-slightly nudge its orbit around the Sun, away from the Earth. It sounds impossible that something as lightweight as a spacecraft, even a spacecraft like DART that weighs more than half a tonne, could possibly nudge something like an asteroid, which weighs millions of tonnes. But you don't need to nudge an asteroid by very much for it to miss the Earth entirely.

These things are not travelling in straight lines towards the Earth, or at least if we found an asteroid heading towards the Earth it wouldn't be

SHUTTERSTOCK



“It sounds impossible that something like DART could possibly nudge something like an asteroid”

travelling in a straight line. They are in orbit around the Sun, along with the planets, including the Earth. You don’t have to nudge that trajectory around the Sun by very much. Just alter its path by fractions of a degree and you’ll miss the Earth by millions of miles.

In summary, kinetic impact is slamming a spacecraft into an asteroid to try and deflect it.

THE ASTEROID SYSTEM IS MORE THAN 10 MILLION KILOMETRES FROM EARTH. HOW DID THE SCIENTISTS NAVIGATE THE SPACECRAFT TOWARDS THE ASTEROID?

We can track asteroids pretty well from the surface of the Earth using ground-based telescopes. DART has got an onboard camera that was directed onto the asteroid.

NOW THE COLLISION HAS TAKEN PLACE, HOW WILL WE ESTABLISH HOW SUCCESSFUL THE MISSION HAS BEEN?

Well, we’re not exactly sure what’s going to happen. There are computer models that have been run that will predict how much this asteroid will be deflected. And there will be predictions about the new orbits of the asteroid after impact. I guess exactly how closely the observational data matches with those models will tell us how much of a success it has been.

But even if this mission doesn’t match the models in the predictions, it will still be a success. The nature of doing any sort of science is sometimes you just don’t know what’s going to happen. And with this mission being the first of its kind, I think the margin for success is very wide. To paraphrase the Apollo astronauts, hopefully it will be a success, but it might be a very successful failure.

DR TIM GREGORY

Tim is a science communicator with a PhD in cosmochemistry. He is the author of Meteorite: The Stones From Outer Space That Made Our World *(£10.99, John Murray).*

THE FUTURE'S BRIGHT...

As a remedy for all the bad news out there, let us prescribe you a small dose of feel-good science. Each issue, we'll give you a rundown of the latest breakthroughs that aim to solve humanity's biggest problems. From burger-flipping robots to GM mosquitoes, here you'll find many reasons to feel hopeful for our future...

SAVING THE PLANET SAVES CASH
The world could save £10tr by 2050 by switching from fossil fuels to renewable energy, a study involving decades of years of energy data carried out at the University of Oxford has found. Thanks to the soaring prices of natural gas and the falling costs of renewables, going green makes more economic sense than ever, the researchers say.

YEARS TO GO

25

CASH BOOST FOR BRAIN MAP PROJECT
Researchers planning to create a map describing the human brain in unprecedented detail have received a $126m (approximately £115m) grant from America's National Institutes of Health. The funding will be used to launch the Center for Multiomic Human Brain Cell Atlas, where researchers will work to better understand how human brains function and age.

20

AN AI THAT GETS YOUR JOKES
Scientists at Kyoto University have created a chatbot with a sense of humour. Named Erica, the bot was trained using conversations recorded during more than 80 speed-dating sessions and is able to respond to human laughter cues. The scientists claim the so-called shared-laughter model could help us to create chatbots that can build empathy in whoever they're talking to.

GETTY IMAGES X4, ALAMY, AERWINS TECHNOLOGIES INC, MISO ROBOTICS

MALARIA-FREE MOZZIES
Last year, malaria infected 241 million people and killed 627,000 in sub-Saharan Africa (mostly children under five) making it one of the world's most devastating diseases. It's transmitted by parasites that live in female mosquitoes' guts. To combat the spread of the disease, researchers at Imperial College London have edited the genes in *Anopheles gambiae*, the main malaria-carrying species of mosquito, to shorten its life and limit the time that parasites have to develop in their guts.

FLYING WITHOUT WINGS
Here's something that would liven up the daily commute: Japanese start-up AERWINS's XTURISMO hoverbike. The futuristic runabout was recently unveiled at the Detroit Auto Show. It can reach speeds of up to 100km/h (62mph) and can run for 40 minutes on a combination of battery and engine power. If you want one, you'll have to cough up an eye-watering £685,000, but the company is planning to release a smaller electric model for £45,000 by 2025.

10

MORE VR, LESS ANAESTHETIC
Patients undergoing hand surgery needed lower doses of sedatives when they immersed themselves in a relaxing virtual reality environment, a study carried out at the Beth Israel Deaconess Medical Center in Boston has found. If it makes it into operating theatres, the finding could reduce the harm caused by unnecessary sedation, the researchers say.

VIRUS-DETECTING MASK
Researchers from Tongji University, China, have developed a face mask that can alert wearers if they have been exposed to airborne coronavirus or influenza particles within 10 minutes. A sensor built into the mask contains a synthetic chemical sensitive enough to detect trace amounts of virus in the air. Once it has detected a virus, the sensor then sends a message to the wearer's smartphone informing them of their potential exposure.

0

ROBOCHEF
It looks like fast food could soon be even faster. California-based tech company Miso Robotics has teamed up with US restaurant chains Wing Zone, Jack in the Box and Chipotle to trial its robot workers later this year. There's Flippy, a burger-flipping, French-fry-cooking bot; Sippy, a drink-dispensing bot; and Chippy, a tortilla-chip-making bot.

COMMENT

THINKING POSITIVELY CAN BE GOOD FOR YOUR BODY, NOT JUST YOUR BRAIN

Looking for an upside in any given situation can improve everything from the immune system to heart health

Positive thinking sometimes gets a bad reputation. Why? Well, because a lot of people think it is steeped in a denial of reality, and believe it can negatively impact our wellbeing as it does not allow us to process difficult emotions or feelings.

However, positive thinking is not about ignoring reality, but rather choosing to focus on potential solutions, being open to new ways of thinking, and finding something to be hopeful for. It can be a useful

strategy for mentally and emotionally dealing with the many uncertainties and challenges of life. Our ability to look for the positives in a situation is known as 'cognitive reframing' and trains us to challenge and change our perspective of a scenario. And if you need any more encouragement to give it a go, a growing number of studies have found that positive thinking can benefit our physical health, as well as our mental health.

For example, researchers from Northwestern University in the US have discovered that people who have a positive attitude are less likely to experience memory decline as they get older. As part of a national study, the team monitored adults at certain points over a decade, each time surveying their mood in the previous 30 days, along with their memory recall. They concluded that having a positive attitude was associated with a less steep decline in memory.

It is not just our brains that benefit from positive thinking, but also our cardiovascular systems. Another study, carried out at the University of Illinois, found that adults who were optimistic were more likely to have better cardiovascular health and lower cholesterol and blood sugar levels. A separate study showed that having a positive attitude could reduce the risk of developing heart disease by 30 per cent.

The thinking behind these findings relates to the stress response that we experience when we have negative, fearful or pessimistic emotions. We have naturally evolved to release stress hormones like cortisol when we feel negative emotions, and these chemicals raise our blood pressure and heart rate, causing damage if chronic.

Stress and low mood can also have an impact on the ability of our immune system to function at its optimum level. Researchers at Wisconsin University concluded that activation of certain brain regions associated with negative emotions appears to weaken people's immune response to the flu vaccine, in the level of antibodies present six months later.

So science is beginning to add weight to the importance of positive thinking on many of our different physiological systems, and this has resulted in positive thinking being studied in relation to increasing our lifespan.

Thinking positively about getting older and a constructive attitude to ageing has been shown to increase the chances of actually living longer too.

We can start to improve our attitude to ageing by recognising that it is inevitable and so we are simply wasting our time by being negative about it, and instead focus this energy on the benefits of ageing, such as more experience and wisdom. We can also cultivate gratitude for living a long life, and foster a determination to remain as fit and healthy as we can. But why does a positive attitude to ageing improve our lifespan? It may be because when we have negative beliefs about ageing, this causes us stress which in turn leads to inflammation.

"We have naturally evolved to release stress hormones like cortisol when we feel negative emotions and these chemicals raise our blood pressure and heart rate, causing damage if chronic and long term"

A study carried out at Yale School of Public Health found that a marker in the blood called C-reactive protein (CRP) increased in response to cumulative stress. The researchers concluded that positive self-perceptions of ageing and longer survival were partially mediated by CRP.

So it appears that positive thinking and trying to reframe our thoughts with a positive mindset doesn't only lead to health benefits through us making better choices because we are feeling good and motivated, but also because of actual biological mechanisms.

It is not all bad news if you have got into a habit of negative thinking, though. A lot of our thinking is the result of habitual, repetitive processes. We can practise cognitive reframing by understanding our thinking patterns, noticing when they arise and challenging them. When we notice a negative thought, we can then take a step back to see it as harmful, but not judge it, and then take an active decision to choose a different and more positive thought instead.

Knowing this, maybe there is even more reason to practise positive thinking strategies every day. It can be difficult to do, but ultimately it is a habit that we can develop and cement, that will serve us day in, day out.

BBC RADIO 1

Listen to Dr Radha Modgil on *Life Hacks* on BBC Radio 1.

DR RADHA MODGIL

(@DrRadhaModgil)

Radha is an NHS doctor, broadcaster and wellbeing campaigner. She is the medical expert on BBC Radio 1's Life Hacks. *Her first book,* Know Your Own Power *(£14.99, Yellow Kite), is out now.*

ILLUSTRATION: DANIEL CRESPO

COMMENT

BABY, YOU CAN DRIVE MY SELF-DRIVING CAR

Human drivers should not be held responsible for accidents caused by autonomous vehicles

In August 2022, the UK government announced a £100m plan to speed up the development and deployment of self-driving vehicles. The plan also calls for new safety regulation, including a bold objective to hold car manufacturers accountable. This would mean that when a vehicle is self-driving, the person behind the wheel will not be responsible for any driving errors. This rule stands in contrast to the US, where courts have faulted human 'backup drivers' for robot-caused accidents. The UK has the right idea – as long as companies don't weasel their way out.

Fully self-driving cars have been on the horizon for quite some time, but are taking much longer than promised to be fully realised. Despite pouring massive resources into research and development, car companies have struggled to account for the sheer amount of unexpected occurrences on roads. Freakish weather is one thing for the vehicles to contend with, but there was also a news story of a self-driving car mistaking the sunset for a traffic light, and another that drove straight into a parked $2m aircraft. So far, the large rollout of automated vehicles the UK is hoping for has remained elusive.

"The research is clear: when a car is doing most of the driving, it's too much to ask of the person in the driver's seat to be vigilant"

Cars are being outfitted with increasingly advanced driver assistance features (like automated steering, accelerating, and braking). These assisted driving systems mean that, until we have reliable full automation, we're going to be dealing with human-robot teams behind the wheel. It also means that when mistakes happen, we need to be particularly careful about who to hold responsible and why.

Robots and humans have different, often complimentary, skillsets. When it comes to driving, robots excel at predictable tasks and can react faster and more precisely than a human. People, on the other hand, are great at dealing with unexpected situations, like an erratic traffic cop or a horse-drawn carriage on the highway. The ideal – at least in theory – would be to combine the skillsets of humans and robots to design a safer driving experience. But in practice, creating an effective human-robot team in the driver's seat is challenging.

One of the cases I teach in class is a 2018 accident in Arizona, where a self-driving Uber struck a woman who was wheeling a bicycle across the road. The car's automated system couldn't decide whether she was a pedestrian, a bicycle, or a vehicle, and failed to correctly predict her path. The backup driver, who didn't react in time to stop the car, was charged with negligent homicide. An investigation by the National Transportation Safety Board identified a number of reasons the hand-off of control from vehicle to driver didn't work, but Uber was not held responsible.

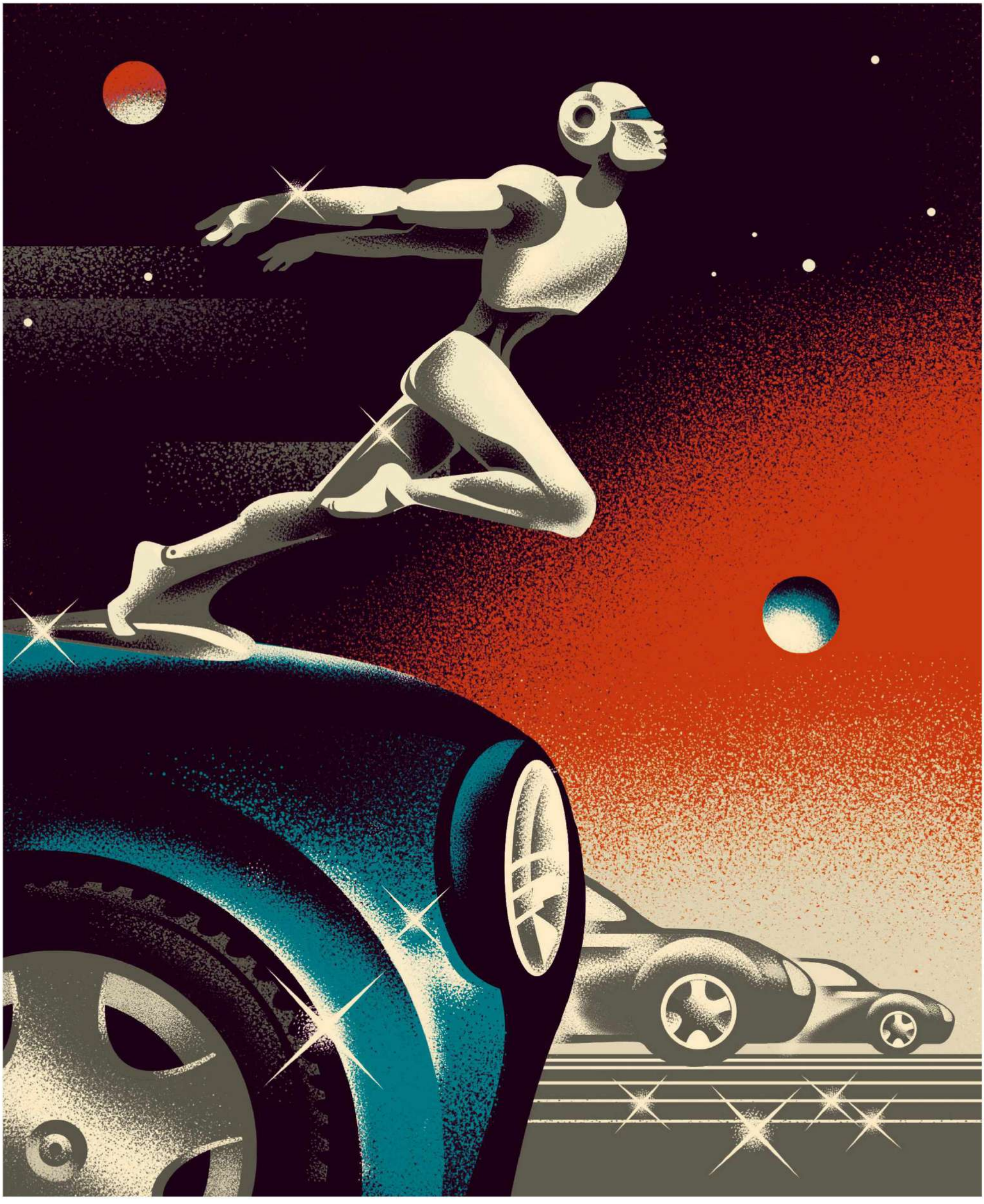
A contributing factor may be what anthropologist Dr Madeleine Clare Elish calls the "moral crumple zone". In class, I present the Uber case as hypothetical. I include hints about human attention spans, and I don't reveal what the driver was doing (watching Netflix on her phone). Even with the case skewed in the driver's favour, about half of the students choose to fault her instead of the car company. According to Elish, this is because people tend to misattribute blame to the human in human-robot teams.

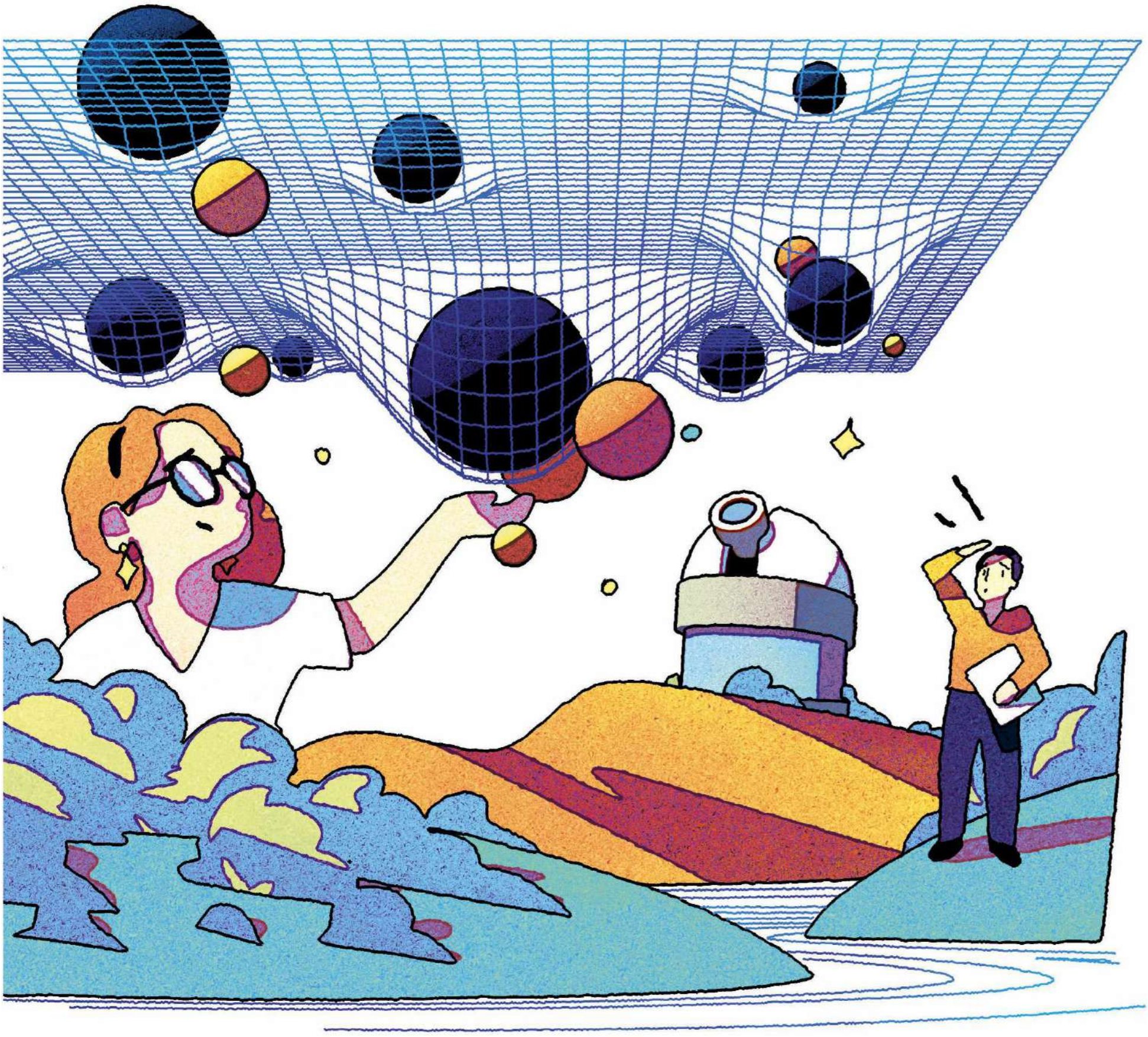
We need to resist this bias, because the research on automation complacency is clear: when a car is doing most of the driving, it's too much to ask of the person in the driver's seat to be vigilant. For this reason, the UK has the right idea. Letting the driver off the hook will set strong incentives for companies to figure out safety in advance, instead of offsetting some of the cost to the public. For example, Tesla UK explicitly states that the Tesla autopilot features "do not make the vehicle autonomous" and that "full self-driving capability [is] intended for use with a fully attentive driver, who has their hands on the wheel and is prepared to take over at any moment." If a disclaimer doesn't shield them, another way car companies might cover themselves is by using systems that don't meet the definition of 'self-driving'. Which would mean going back to more hand-offs between car and driver – and more drivers blamed when something goes wrong.

With the UK investing so much capital in self-driving, we may ultimately see some new technology, and a rollout of robot vehicles on predictable routes. Despite the fairly slow pace of development and deployment, it's an exciting prospect. With traditional cars, more than 90 per cent of road accidents are due to human error, so one thing is clear: in the future, streets filled with autonomous drivers will be safer. The only question is how we handle the long and winding road to get there.

DR KATE DARLING
(@grok_)
Kate is a research scientist at the MIT Media Lab, studying human-robot interaction. Her book is The New Breed *(£20, Penguin).*

ILLUSTRATION: VALENTIN TKACH





COMMENT

GETTING TO THE HEART OF THE (DARK) MATTER

We've mapped it, but the exact nature of dark matter remains elusive. And for most astronomers that's okay

In early August, astronomers announced that they had created a map of dark matter from the early Universe. Dark matter is the mysterious, invisible stuff that astronomers say underlies all structure in the cosmos.

Articles reporting the achievement described the innovative observational technique of searching for tiny distortions of patterns in the cosmic microwave background radiation, the backlight of the Universe

that originates from the Big Bang. These distortions appear because mass bends space, even if that mass belongs to an invisible kind of matter.

Tellingly, these reports did not delve into the mystery of what dark matter is, or question whether it even exists. For most astronomers, most of the time, dark matter's fundamental nature is entirely beside the point. Despite having never directly detected it, scientists have good reason to believe that dark matter is real.

The first story that everyone tells is that galaxies seem to be rotating at impossible speeds. The stars at the outer edges of spiral galaxies are orbiting around the centre so quickly that if something wasn't providing extra gravity to hold them in, they would have already escaped into intergalactic space, like children flung off a merry-go-round that's spinning too fast.

The proposed solution: an invisible, intangible substance – presumably composed of a collection of particles our Earth-based experiments have all missed – surrounds and penetrates the misbehaving galaxy, and its mass provides the extra gravity the observations require.

It's not unreasonable to point to another possibility: maybe we don't need something new to produce more gravity; maybe gravity just acts differently from what we thought. This has been the main approach of dark matter sceptics in astrophysics, and when it comes to galaxy rotation, it seems to be an appealing solution. These modified gravity models work so well to solve the rotation problem that articles regularly appear in papers and magazines proclaiming that dark matter has been disproven by a simple tweak to Newton's (or Einstein's) laws.

But there's a reason why we haven't all thrown out dark matter and embraced the demise of gravity as we know it: the best evidence for dark matter comes from cosmic phenomena occurring on scales much larger than any galaxy, where there are fewer observational complications and where the agreement with theory is incredibly precise.

That preponderance of evidence would be compelling even if we completely ignored galaxy rotation, and there has yet to be a modified gravity theory that can compete with dark matter when it comes to everything else: galaxy shapes, galaxy cluster motions, gravitational lensing, elemental abundances from the early Universe, the distribution of galaxies on the largest scales, and even the patterns in the cosmic microwave background light itself.

Even accepting that the astrophysical evidence is strong, it's understandable to remain uncomfortable with the notion of adding a dark matter particle to the zoo of discovered species without any concrete detection of the particle itself.

Some of the simplest theoretical possibilities for dark matter's particle properties have already been ruled out. But rather than give up entirely, astronomers and physicists are constantly searching for new, creative ideas for what dark matter might be and why it hasn't shown up yet. In spite of the experimental no-shows, when all the evidence is taken into account, the idea that the Universe is overrun by invisible particles just fits the data best.

In cosmology, we sometimes loftily describe our mission as "solving the mysteries of the Universe", but in a day-to-day sense, our job is to build and test mathematical models to describe the data we collect. Not detecting a particle in a detector might make us uncomfortable, but it doesn't cancel out any of the ways in which we see dark matter's influence in the cosmos. And there's no indication that dark matter ought to be something that interacts with detectors at all.

It's still possible some other solution will be found. But whatever it is, it will have to look, observationally, exactly like a collection of invisible, untouchable particles making up most of the matter in the Universe.

Whatever dark matter is, we can be grateful for its role in bringing all that ordinary matter together, and rest assured that it's likely to continue doing a great job of keeping our Sun from flinging itself off into the void.

"It's understandable to remain uncomfortable with the notion of adding a dark matter particle to the zoo of discovered species without any concrete detection of the particle itself"

NERISSA ESCANLAR ILLUSTRATION: KYLE SMART

DR KATIE MACK
(@AstroKatie)
Katie is a theoretical astrophysicist. She currently holds the position of Hawking Chair in Cosmology and Science Communication at the Perimeter Institute for Theoretical Physics.

PCSPECIALIST

PORTABILITY. RECONFIGURED.

Experience the ultimate in mobile computing with a custom laptop from PCSpecialist. Our laptop configurator puts you in control, allowing you to configure a custom laptop to meet your exact requirement.

CUSTOM BUILT LAPTOPS FROM PCSPECIALIST

WWW.PCSPECIALIST.CO.UK

PCSpecialist

PCSPECIALIST

GET AN EXCLUSIVE **£15 DISCOUNT**
WITH BBC SCIENCE FOCUS USING CODE: **BBF22**

ELIMINA® SERIES

- 12th Gen Intel® Core™ CPUs
- NVIDIA® GeForce GTX 1650 / RTX 3050 / 3050Ti / 3060
- 144Hz FHD Screen (72% NTSC)
- Multi-Colour Backlit Keyboard
- Windows 11 Home

Range from

£920.00*

IONICO® SERIES

- 12th Gen Intel® Core™ CPUs
- NVIDIA® GeForce RTX 30 Series
- 240Hz QHD Screen
- Magnesium Alloy Chassis
- Windows 11 Home

Range from

£1,450.00*

DEFIANCE® SERIES

- 12th Gen Intel® Core™ i7 CPUs
- NVIDIA® GeForce RTX 30 Series
- 144Hz or 240Hz FHD Screen
- Thunderbolt™ 4
- Windows 11 Home

Range from

£1,350.00*

CONFIGURE YOURS AT WWW.PCSPECIALIST.CO.UK

*Prices are including VAT and are correct at time of printing, but subject to change. Images are for illustration purposes only, components may differ in aesthetics and brand.

REALITY CHECK

SCIENCE BEHIND THE HEADLINES

Your inner child | Sewage | Grieving the Queen

REVIEW

YOUR INNER CHILD: WHAT IS IT, WHAT'S UP WITH IT AND DOES IT NEED HEALING?

Recent online articles have listed the signs that reveal your inner child is wounded, or that your inner child needs healing. But is there any real psychology behind this?

"A hard-nosed neuroscientist might dismiss the idea of an inner child as fanciful. But in other fields the notion is long established"

BBC *Visit the BBC's* Reality Check *website at* ***bit.ly/reality_check_*** *or follow them on Twitter* ***@BBCRealityCheck***

Have you noticed the spate of advice articles claiming to help you tap into your 'inner child'? Some of them suggest this inner infant could be to blame for your relationship troubles, and there are others that promise to show you ways to start 'healing the wounds' your child within may have suffered. Online influencers are apparently tuned into the trend – you can find many of them posting photos of themselves riding tricycles or doing other seemingly childish things alongside boasts that they're tapping into their inner child.

So, what's this all about – do we really have such a thing as an 'inner child'? And do you need to heal it?

WHAT IS AN INNER CHILD?

The answer is that it depends on who you ask, and on whether you're being literal or metaphorical. A hard-nosed neuroscientist might dismiss the idea of an inner child as fanciful. But in other fields the notion of an inner child is long established. Both Sigmund Freud and Carl Jung referred to an 'inner child' in their writings, and for several decades now, many serious schools of psychotherapy have taught that, as adults, we have a child within. The late US self-help evangelist and best-selling author John Bradshaw also gave the concept a popular boost with his 1990 book *Homecoming: Reclaiming And Championing Your Inner Child*.

WHAT DO PSYCHOLOGISTS SAY?

The different therapy schools describe this 'mini me' of the psyche in various ways. For instance, there's internal family systems therapy (IFS), developed by the US therapist Robert Schwartz in the 1980s. IFS states that we have a multiplicity of 'parts' within us, one of which is our inner child – or even inner children – which is the different aspects of ourselves formed at different ages, each with its own memories and emotions. Crucially, this approach teaches that if you suffer some kind of trauma or abuse early in life, then this experience can wound one or more of your child parts. You carry this wound with you through life and it can potentially cause conflict between the different parts of yourself.

A related but distinct approach comes from what's known as schema therapy, developed by the US psychologist Jeffrey Young in 1990. It states that we all have various modes for relating to other people and the world, some of which are 'child modes', such as the 'vulnerable child' or the 'angry child'. In times of emotional stress, we can regress to these modes, especially if we experienced trauma or neglect early in life.

These ideas are also connected in various ways to 'attachment theory', which sees the way we conduct our adult relationships as being shaped, at least in part, by the ways we were treated by our caregivers as children. So, drawing on attachment theory, a therapist might help a client look back to their childhood relationships, especially if they were harmful, and help them to develop new, more secure ways of relating to other people.

Of course, the most mainstream and popular therapy today is probably cognitive behavioural therapy (CBT) and this approach can be linked to the concept of an inner child too. For instance, one aspect of CBT is about identifying and challenging unhelpful 'automatic thoughts' that ➤

GETTY IMAGES X2

Your younger self may have experienced something that's affecting the way you live as an adult

spring to mind, such as "I'm bound to make a fool of myself". In a 2018 article in the *American Journal Of Psychotherapy*, a pair of CBT practitioners argued that these sorts of automatic thoughts might helpfully be thought of as learned early in life and then incorporated into your 'child mode'.

CAN AN INNER CHILD BE HEALED?

Psychotherapeutic approaches that believe in an inner child use various techniques to help people connect with and heal this aspect of themselves. For instance, a therapist who practices IFS therapy will help their client or patient improve the relationships between the different parts of themselves – including by bringing the 'manager' parts into conversation with the 'exiles', which can include the inner child or children from earlier in life. They'll likely also help clients come to terms with traumatic events from their past – to heal the inner child.

Meanwhile, a therapist using schema therapy might use a therapeutic technique known as 'chairwork'. This exercise sees them place two chairs opposite each other and invite a client to take one chair and ask them to adopt a 'healthy adult mode', so they can speak to and nurture their 'vulnerable child mode', which they imagine is sitting in the empty chair opposite.

So, what to make of the online pop-advice articles that promise to help you heal your inner child? In reality, it's difficult to engage in this kind of deep therapeutic work alone – and if you have experienced serious trauma in the past, it's especially sensible to take great care and consider consulting a mental health professional. These notes of caution aside, many of the popular articles use the notion of an inner child simply to encourage readers to practise self-compassion (nurturing themselves as they would a vulnerable child) or to think about and challenge harmful self-beliefs they might have internalised when they were younger – all of which seems fairly innocuous.

by **DR CHRISTIAN JARRETT**
Christian is a psychology and neuroscience writer. His latest book is Be Who You Want: Unlocking The Science Of Personality Change *(£14.99, Robinson).*

ANALYSIS

SEWAGE: WHY IS RAW WASTE PUMPED INTO OUR SEAS AND CAN WE FIX IT?

The UK's ageing infrastructure is struggling to cope with increased rainfall and a growing population, and this means sewage is being discharged into our seas and rivers. Just when you thought it was safe to go back into the water...

Recent months have seen fresh concerns over a wave of discharges of untreated raw sewage in the UK. In early September, the Safer Seas and Rivers Service, which is run by the charity Surfers Against Sewage, issued pollution warnings for more than 100 beaches.

GETTY IMAGES

ABOVE A sewage network that's unable to deal with extreme amounts of rainfall means more sewage is finding its way onto Britain's coast

Rising awareness of these events has led to public anger about the situation. But why is this happening now, and what can be done about it?

Unlike some other countries, which have split drainage systems for rainfall and sewage, the UK has a combined system that accepts both. It's managed by water and sewage companies, who, if all is well, biologically treat the sewage before discharging it into the environment. But under extreme circumstances, such as exceptionally high rainfall, these companies are allowed to discharge untreated sewage. This is to avoid capacity being reached and sewage coming back into people's homes and businesses, says Dr Sarah Purnell, a researcher in aquatic environment health at the University of Brighton.

The legal model works relatively well when these events happen infrequently, notes Purnell. And since the sewage is mixed with stormwater on these occasions, it should be highly diluted.

The problem is that these legal discharges are happening far more than many people realised and may be more concentrated. Michelle Walker, technical director of The Rivers Trust, says overflows of untreated sewage are being routinely used even when it hasn't been raining.

"If you're going to swim recreationally after rainfall events, you're more likely to come across discharges"

She attributes this to three causes: investment in the sewer network and treatment facilities failing to keep pace with pressures such as population growth; more intense rainstorms due to climate change; and increased runoff from urban areas as more green spaces are paved over.

As well as being unpleasant, people swimming or boating in untreated wastewater are at risk of coming into contact with pathogens and developing gastrointestinal illnesses, or respiratory, eye and ear infections.

"If you're going to swim recreationally after rainfall events, you're more likely to come across discharges and the chance of you getting sick is likely to be greater," says Purnell. Sewage discharges also significantly impact the ecological quality of rivers, she adds.

Purnell notes these overflows are not a new issue, but have become more visible as the UK has begun to monitor them more effectively. Since 2020, the Environment Agency has required water companies to monitor and report on how often and for how long storm overflows are used. "[But] we still don't know the volume of wastewater that gets discharged," says Purnell.

Hugo Tagholm, chief executive of Surfers Against Sewage, says the water industry and regulatory bodies have cut financial corners in favour of "greedy shareholders". "Our beaches, rivers and lakes are some of our most precious natural resources, but water companies are treating them as an open sewer, devastating wildlife and posing serious health risks to all those who attempt to enjoy them."

An Environment Agency criminal regulatory investigation into sewage discharges at wastewater treatment works in England is currently underway. Its initial analysis in May found that there "may have been widespread and serious non-compliance with the relevant regulations".

In response to concerns over sewage discharges, the government announced a plan in August requiring ➲

CAUTION
Potential for reduced bathing water quality
Water quality may be affected by rainfall / pollution
DATE: 07.09.22
This notice will be removed once the potential risk has passed

A notice from the Environment Agency alerts bathers to potential post-rainfall sewage discharge in Falmouth this September

water companies to invest £56bn to improve all storm overflows by 2050 (2035 for storm overflows near designated bathing waters and certain protected natural sites).

But Walker says the government's plan is doesn't go far or fast enough to tackle the problem. She says stronger regulation and enforcement of the privatised water industry is needed. She also calls for the government to "work with nature" to reduce the pressure of rainfall entering the sewer network. Measures to do this include increasing the use of water butts and rain gardens to reduce urban runoff, using wetlands to clean up sewage pollution, and expanding ponds and dams upstream as a form of natural flood management, she says.

These measures would also reduce agricultural pollution runoff, keep rivers flowing in dry periods, reduce flood risk and help to tackle the climate and biodiversity crisis, she says.

Purnell also says nature-based solutions are useful. "Anything we can do to slow down runoff or infiltration of rainfall to the sewage network will help."

Areas with the most discharges could be targeted to implement these sustainable drainage solutions, she adds. And all new housing estates and new builds should also be thinking about slowing down water paths.

But water and sewage companies also need to invest in upgrading their infrastructure, Purnell says, through storage or increased treatment capacities. A longer-term solution would be to redesign the UK's system to deal with rainfall runoff separately to sewage, she adds, but accepts this would be difficult and expensive and is the "least realistic" solution in the short term.

Meanwhile, the UK needs to focus on gaining a real understanding of the current discharges, according to Prof Andrew C Johnson, environmental research scientist at the UK Centre for Ecology and Hydrology. He says two critical pieces are missed by current monitoring: the volumes of untreated sewage being discharged, and whether it is happening more frequently now than before. To truly assess the risks, he explains, both the volume of sewage overflows and the water quality downstream from these overflows need to be measured.

by **JOCELYN TIMPERLEY** *(@jloistf)*

Jocelyn is a freelance science, climate and environment journalist from Scotland.

COMMENT

GRIEF: WHY DO WE MOURN PUBLIC FIGURES?

Few people knew her personally, and yet many of us felt some sense of loss for the Queen

On 8 September 2022, Queen Elizabeth II died at the age of 96. At the time of writing, the UK is in the midst of a prolonged period of public mourning.

Regardless of your thoughts about the monarchy, it's undeniable that countless people are genuinely saddened by the Queen's passing, and are experiencing profound grief. This is a fascinating phenomenon, because grief is a complex and demanding process. So, why would so many experience grief over the loss of someone they've likely never met, and who almost certainly had no idea that they existed?

Rather than an anomaly, such grief is actually commonplace. It's because of how our brains work.

Humans are incredibly social creatures. It's the basis for our dominance of the planet. We form emotional connections with other individuals like no other species. But despite what many assume, this need not be a mutual thing. It's entirely possible for us to become deeply emotionally invested in someone who doesn't even know we're there.

Anyone who's ever had a crush on someone from afar, or who's felt like a podcast host is a close personal friend, will know what it's like to be in a parasocial relationship. This is a relationship that's entirely one-sided, with all the emotional investment coming from one person towards another, while the latter is largely oblivious to the whole thing.

Parasocial relationships are the basis of celebrity culture and every sort of fandom. After all, it's entirely possible for people to develop deep and powerful emotions for individuals who don't even exist.

Taking this into account, it doesn't seem so odd that people would develop genuine affection for a real individual who was a part of their world for decades. Accordingly, they would also experience grief when that person dies. And because human sociability is so important, we're often keen to express (share) that grief with others, who feel similarly. It's another way of bonding, of reinforcing our remaining connections, at a time when we've lost one.

But humans aren't just social. We're also hierarchical; we instinctively care about status, about being looked up to by others, and looking up to others in turn. We learn from others and the examples they provide. From

GETTY IMAGES X2

"Why would so many experience grief over the loss of someone they've likely never met?"

back in the early days of our species, where aspiring to be like the best hunters or warriors was a useful survival trait, to the present day, we're inclined to look up to, identify with and want to emulate the visibly more successful members of our society.

In the case of the Queen, there's a lot of this at work. In the UK, we were constantly told that she was the best of us, that she represented us to the world, with grace, dignity and decorum. Many people identified with the Queen and felt that she was 'on our side'. Yes, she was immensely privileged and wealthy, but that wealth was also 'ours', in a way that the vast fortunes of folks like Jeff Bezos aren't.

Of course, many will point out that this representation of the Queen is an almost entirely fictional construct, maintained by established interests to preserve the status quo, and behind closed doors things were very different.

ABOVE People of all ages, from all walks of life and from all over the world expressed sympathy for the death of the Queen

The thing is, even if this were 100 per cent true, those 'closed doors' are key. The vast majority, living busy lives with concerns and priorities of their own, will only know/see the portrayal of the Queen presented to them. It's entirely reasonable for them to look up to and admire this 'portrayal', and experience heartache when it's gone.

And because we value status so much when around similarly minded people, it can lead to one-upmanship in the expression of grief. Hence we're seeing such overt, even competitive-seeming, expressions of grief – because for many, it's not enough to just be sad, they need to be the saddest.

While the death of a high-profile and beloved individual often leads to widespread public mourning, the Queen's passing is affecting on an even more profound level, because the Queen was visibly the (nominal) head of British public life for seven decades. For someone living in the UK, she was just 'there', all day every day. On our money, our stamps, in the anthem, involved in all our laws and politics. She was essentially inescapable.

Regardless of your feelings towards her, if you're a British person under 70 (so among the vast majority of Brits), the Queen has been part of your everyday existence for your entire life. Prime ministers and politicians came and went, but the Queen remained, like the white cliffs of Dover.

Her death shows that a part of our world that seemed reliable and unchanging, isn't, which means the world is suddenly, and fundamentally, more uncertain. And the human brain doesn't like uncertainty, it causes stress and discomfort.

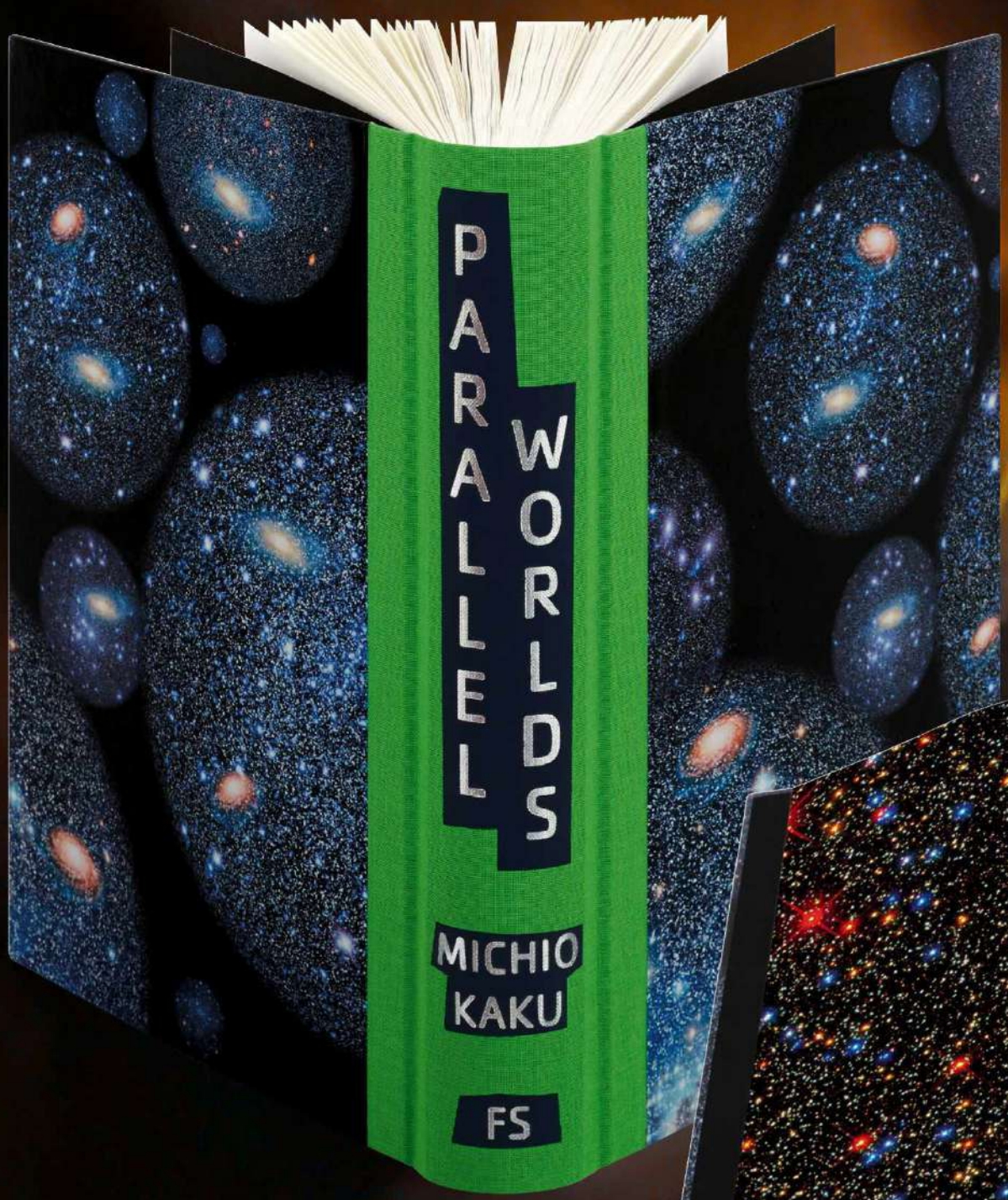
Even if you didn't like the Queen, or were just ambivalent about her, you may still find yourself reacting to her death with sadness. Because she was a reliable part of everyday life. And realising something you rely on is no longer there is distressing. **SF**

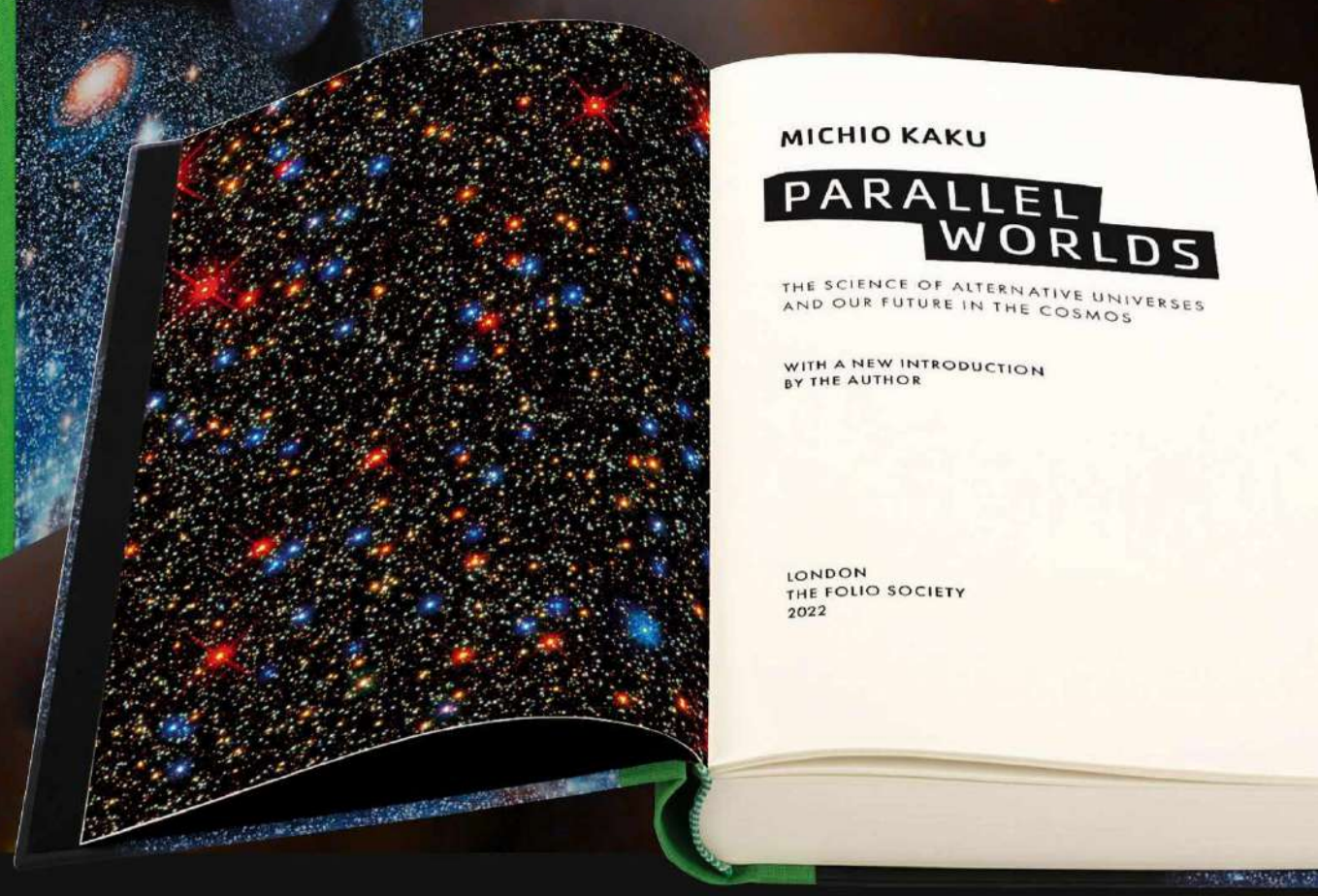
by **DR DEAN BURNETT** *(@garwboy)*
Dean is a neuroscientist and author. His next book, Emotional Ignorance: Lost And Found In The Science Of Emotion, *is released in January 2023.*

MICHIO KAKU

PARALLEL WORLDS

With a new introduction by the author





'We are entering what may be the golden age of cosmology… a great time to be a physicist and a voyager on this quest to understand our origins and the fate of the universe.'

Michio Kaku from his introduction

The Folio Society

75 FOLIO at SEVENTY-FIVE

Exclusively available from

FOLIOSOCIETY.COM/PARALLEL

Image: Collaboration, D. Padgett (*GSFC*), T. Megeath (*University of Toledo*), and B. Reipurth (*University of Hawaii*))

INNOVATIONS

PREPARE YOURSELF FOR TOMORROW

INNOVATIONS

ANALYSIS

FITNESS TRACKERS

Should they be used as a diagnostic tool? **p44**

FIVE OF THE BEST

CAMERA GIMBALS

Handheld tools for smooth views **p46**

NEW TECH

IDEAS WE LIKE

The gadgets we're lusting after this month **p48**

↑ Fly the first-person-view skies. Find out more on p48

36%

The percentage of smartwatch sales accounted for by Apple in 2022 (Counterpoint Research)

$175.6bn

The value of the digital health tech market in 2021 (Grand View research)

35%

The percentage of people in the UK who owned a wearable in 2021 (Trajectory Partnership)

ANALYSIS

In the right hands, wearables could revolutionise healthcare

We spoke to **Prof Amitava Banerjee**, a cardiologist and clinical data scientist, to better understand how smartwatches and fitness trackers could change medicine

For years now, smartwatches from various brands have allowed you to track your health and wellness. They let you count your steps, check your heart rate and set reminders to stand up now and then or, if you somehow forget, they'll give you a gentle nudge to breathe.

But recently, the likes of Apple, Withings and Fitbit have begun to move from wellness to more detailed health analysis. You can perform an ECG, monitor for irregular heart rhythms and, most recently, measure your temperature to track ovulation.

These advances take health tracking into a new, grey area. As well as providing basic measures of fitness and performance, they're now starting to gather the kind of data that could be used to predict illnesses or health issues.

In fact, companies including both Apple and Fitbit have already been involved with studies to see if their trackers can be used as diagnostic tools.

So can your new health-tracking smartwatch spot an abnormality simply by keeping an eye on your heart rate and activity levels? And, more importantly, can this information be used to inform a conversation with your doctor? We spoke to Prof Amitava Banerjee, a cardiologist and professor of clinical data science, to find out...

"BOTH APPLE AND FITBIT ALREADY HAVE BEEN INVOLVED WITH STUDIES TO SEE WHETHER THEIR TRACKERS CAN BE USED AS DIAGNOSTIC TOOLS"

CAN BIG TECH AND DOCTORS COLLABORATE?

"Until any device, algorithm, or statistical model has been externally validated and I've seen the data or it's in the public domain, I can't trust the producer of the watch to tell me that it's going to make my health better. There needs to be published data, ideally from clinical trials," says Banerjee.

For a big tech companies, the first step into health and diagnosis is research. Some of the major companies in health tech have performed studies, but Banerjee believes that this existing research hasn't been rigorous enough and needs improving if it's going to be trusted.

Even with further research, there's another issue for tech companies entering the medical field to deal with: the use of the data they're creating in a practical setting. Will the information they can provide be useful for doctors, or is it more likely to interfere with their work?

"First, show whether your algorithm works, then go to the doctor and see how they would use this. If you look at pulse checkers for example, they can affect the doctor's workload adversely, by bringing in people who are the 'worried well' every time their pulse goes over 70. You might divert care towards the people who don't necessarily need it, and potentially cause further inequality in the healthcare system."

PUTTING THE USER FIRST

There are three parties in the debate over health tech advancements: the tech companies, the healthcare practitioners and, most importantly, the users. For wearables and health tech to work, the user needs to come first.

"The digital health market is huge, and the [media] coverage focuses on all the money to be made. The starting point should be about helping people and bettering their health," Banerjee says.

All the brands operating in this field are targeting a niche group of people, more specifically those who are in good health. These people are then fed large amounts of information without a full explanation of what to do with it.

"These devices aren't necessarily reaching the people who I most want it to reach – the people that need the healthcare most. The people who are being reached aren't being given full information, either. I'm able to buy the right phone, but I might not be able to know what makes the tracker I'm interested in good. Or I might not be able to find out what makes one ovulation checker accurate versus another one. There isn't enough information."

The other problem the tech companies face is the need to create an ecosystem that includes the healthcare practitioners and the users. Banerjee hopes for a co-designed model that could help everyone involved.

"It has to be good for the patient, but it has to also be usable by the healthcare providers. If we're going to a place where the patient owns – or at least can manage – the data, that could be a good place.

"It's becoming difficult in healthcare to have all the information we need. It's hard to have all the things I need to know about you when I see you in the clinic. If you had all your medical information in one place it would make it a lot easier. But of course, there are concerns over a company holding all of your medical data."

They don't just tell time. Smartwatches can track all sorts of things, including your activity levels

THE FUTURE OF WEARABLES AND HEALTH

Despite his concerns, Banerjee believes that tech companies have the potential to greatly improve the health and diagnosis industry.

"Phones and wearable technology are some of the most scalable things that we could have in healthcare. People are right to be hugely optimistic about what we could do with them. We just have to overcome some barriers first."

Moving forward, Banerjee believes that tech companies can bring funding and innovation to the field that wouldn't otherwise be achievable. This would first take more public research, communication with medical professionals, and a leap into regulation.

"Wearable companies need to be brave and leave the health and wellness space to enter the medical and the disease arena. There's more regulation but a much greater impact. Apple and others are doing things that traditional medicine could never do. We can't publicly fund this level and scale of innovation. With a little more communication with medical professionals, health tech could be great."

The five best camera gimbals

An essential bit of kit for smoother video and better selfies, says photographer **James Abbott**

DJI OM 5

£139, dji.com

Small, lightweight and pocket-sized, the DJI OM 5 is a three-axis phone gimbal featuring a unique detachable magnetic phone clamp, allowing you to attach and detach your phone quickly and easily. Meanwhile, a 215mm telescopic arm makes the gimbal longer to provide greater distance between you and your phone, which is ideal for vlogging and selfies.

The companion DJI Mimo app provides functionality and control for both photos and videos, along with useful tutorials. The controls are well positioned and responsive, while the powerful motors do a great job of keeping your phone steady.

The OM 5 comes with a storage bag, wrist strap and a small tripod that can be used to stand the gimbal independently. The OM 5 also includes Active Track 4.0 for following moving subjects, which can be used when the gimbal is handheld or mounted on its mini tripod.

Zhiyun Smooth 5 Combo

£209, store.zhiyun-tech.com

A professional-level phone gimbal may seem strange, but these days many people capture videos for work, pleasure and social media using their smartphone. So a high-spec three-axis gimbal like the Zhiyun Smooth 5 Combo is the perfect choice if you're looking for advanced functionality.

The compromise for extra features is a slightly larger and heavier gimbal than entry-level options. The features include four shooting options for different situations, various modes including Hyperlapse and Panorama, dolly zoom, subject tracking and a focus/zoom ring. Plus, the gimbal motor doesn't block the phone, which can be rotated a full 360°.

The ZY Cami app works seamlessly with the gimbal and provides access to the camera and its controls. The Zhiyun Smooth 5 Combo comes with a case, mini tripod, charging cable and a magnetic fill light, with up to 300 lumens of brightness.

DJI Pocket 2

£339, dji.com

If you're looking for the ultimate all-in-one solution, the DJI Pocket 2 is a pocket-sized camera and three-axis gimbal that you can carry anywhere. It's smaller and lighter than a phone gimbal at just 117g, which makes it incredibly portable and comfortable to use with one hand. With the ability to shoot video in 4K at up to 60fps, and photos up to 64MP, you'll never feel that your creativity is limited.

The Pocket 2 can be used as a standalone device with the controls on the handle, or it can be plugged into Android and iOS phones using the included USB-C and Lightning connector. By using your own phone, you'll have a much larger screen for composing your photos and videos than the tiny one on the Pocket 2.

The level of stabilisation is highly effective and includes several modes for different shooting situations. Video modes include everything you'd get with a modern smartphone, but you can also enjoy HDR video and the ability to shoot in the Normal colour profile for straight-out-of-camera video footage, or in D-Cinelike for colour grading in professional workflows.

Manfrotto MVG220

£330.95, manfrotto.com

With a maximum payload of 2.2kg and a weight of 1.1kg, the Manfrotto MVG220 is a compact and lightweight professional gimbal offering a variety of useful features that extend its use beyond video stabilisation. Alongside the gimbal-locking modes for achieving different gimbal movements, the MVG220 offers Portrait mode to flip the camera upright, Selfie for vlogging, Inception for rotating the camera, and Timelapse for combining gimbal movement with interval shooting.

The MVG220 can be operated using the onboard controls and LCD touchscreen, or remotely via the Manfrotto app. Plus, with a variety of connectors included for different cameras, you can stop and start recording using the gimbal. And if the camera is compatible, you can adjust additional camera settings such as ISO, exposure compensation and white balance.

The MVG220 is easy to set up and use with a comfortable feel in the hand, while the included handle is great for additional stability and low-angle shooting. The gimbal has a robust polystyrene case and is quick to set up after balancing.

Zhiyun Weebill 3 Combo

£499, store.zhiyun-tech.com

Zhiyun's Weebill 3 Combo is aimed at video stabilisation, with no additional features beyond a built-in noise-cancelling microphone and an LED light. The latter offers up to 1,000 lux illuminance and an adjustable colour temperature of 2,600 to 5,400K, allowing you to go from daylight balanced to warmer light. These are certainly useful in situations where you have minimal kit and need a quick fix.

The Weebill 3 is easy to set up and provides smooth movements and great stabilisation throughout the gimbal modes. Movement can be controlled using the controls or remotely using the ZY Play app. And with a record button on the Weebill 3, you can use the included cables to connect a variety of cameras and stop or start recording without touching the camera.

The wrist strap helps redistribute the weight of the gimbal, camera and lens, making it comfortable to hold and use.

Ideas we like...

Our pick of the month's smartest tech

↓ ...a drone that makes you feel like a bird

Want to soar through the sky like an eagle? You could strap on a wingsuit, but for those of us looking for a somewhat safer option, DJI's new first-person-view drone could do the trick. The DJI Avata uses a headset to allow you to see exactly what the drone 'sees'. While this is nothing new, DJI has beefed up the drone and included a host of safety features, which means that newbies can rocket through the sky without fear of crashing. You even get a motion controller, allowing you to move the drone with hand gestures.

DJI Avata
£989, store.dji.com

↓ ...innovative phone technology

Do you need a smartphone that can fold? Do you need a device that costs a £1,649? For most people, the answer to both those questions will be no, but that hasn't stopped Samsung releasing the fourth version of its Galaxy Z Fold series. This folding smartphone can open into a full tablet, yet still offers a surprisingly slim design when closed, and comes with an impressive camera and high-quality screen.

Samsung Galaxy Z Fold4
£1,649, samsung.com

↓ ...solar-charged headphones

Fed up of charging your devices each day? Adidas's latest headphones could help. They offer 80 hours of playtime, and charge via light – both natural and artificial. That means you can get a full battery just by walking around with them on your bonce. While solar-charged headphones aren't anything new, Adidas has designed them to be sweatproof and splashproof, with washable parts so you can de-stink them after the gym.

Adidas RPT-02 SOL
£199.95, adidasheadphones.com

↓ ...the ultimate standing desk

Ergonomic office gear is cool nowadays, thanks mostly to a cult-like obsession with standing desks. While most standing desks are limited to a rise and fall motion, start-up Lumina has decided to go even further. Its desk is fitted with an always-on ambient display, so you can track your social media, use Spotify or monitor finances straight from the desk. You can also wirelessly charge your phone from anywhere on the surface, and set timers for your desk to rise or fall.

Lumina Desk
£TBC, getlumina.com/desk

↓ ...a portable air massager

For the average person, on-the-go air massagers might seem ridiculous, but for avid marathon-runners or professional athletes, the Hyperice Normatec Go seems like a worthy investment. The wearable sleeves slide onto your calves, delivering targeted compression that you control via an app to help ease soreness and inflammation. They will make your legs look a bit like RoboCop's, but that feels like a worthwhile exchange to reduce post-exercise pain.

Hyperice Normatec Go
$399, hyperice.com

IDEAS WE DON'T LIKE...

...CREEPY FACES IN THE METAVERSE

The metaverse was a huge gamble for Mark Zuckerberg's Meta, and right now, he seems to be losing that bet. While showing off Meta's new game *Horizon Worlds* for the Rift S and Quest 2 VR headsets, Zuckerberg unveiled his avatar for this metaverse experience. Stood in front of a blurry Eiffel Tower, the low-resolution, terrified-looking version of Zuckerberg was met with much hilarity and scorn online. Early reviews of the game report non-stop bugs, but at least it can successfully replicate Zuckerberg's dead-behind-the-eyes stare.

Horizon Worlds
oculus.com

...FOOTBALL SCARVES WITH PRIVACY PROBLEMS

Football is intense, even if you're just an onlooker. Sweat, tears and an increased heart rate are all accepted side effects when you're watching your team play. Now, though, your chosen club can know *exactly* how you're feeling during a game, especially if you're a Manchester City fan. The legendary club has created the Connected Scarf that tracks your temperature, blood flow, and movement, and can even tell if you're lying. What will this information be used for? To "show how deeply fans are impacted by actions on the field," Manchester City says. Just *asking* would have been cheaper and much less creepy.

The Connected Scarf
mancity.com

ADVERTISEMENT FEATURE

BUILDING ON A MILLENNIUM OF ARAB INNOVATION

The Middle East was once at the forefront of invention. Algebra, universities, inoculation against disease, coffee, windmills, the arch and even the three-course meal: all had their genesis in the region. Yet over the past 150 years, the focus on innovation on a global scale has not been as sharp as it once was.

That's why, as we enter the second quarter of the Digital Century, the Kingdom of Saudi Arabia will reinvigorate that inventive tradition with a range of new research, development and innovation priorities aimed at addressing the most pressing issues affecting mankind today.

Through a focus on Health and Wellness, Sustainable Environment and Supply of Essential Needs, Energy and Industrial Leadership, and Economies of the Future, the newly established Research, Development and Innovation Authority (RDIA) will be a steward for the Kingdom's work with global partners, deploying a multi-billion-dollar budget over the coming years.

We are determined to help make world-class healthcare accessible and equitable across society. As an existing leader in digital health, the Kingdom will continue investing to advance the technology even further. As we demonstrated during the Covid-19 pandemic, this is an area in which we lead the world.

Saudi Arabia is intent on addressing not only domestic but also global health challenges through focusing on ultra-early disease detection and biotechnology to prevent the blight of illnesses such as cancer and chronic heart disease from ending lives prematurely.

A good life isn't limited to good health. Security of food, water and energy are vital for happiness and wellbeing.

The world's largest solar-powered desalination plant is located in Al Khafji in Saudi Arabia and we continue to invest in innovation to make desalination environmentally friendly, more accessible to many more households and businesses, cheaper to achieve and, crucially for food security, able to be used easily in farming.

Saudi Arabia has prospered over the past century thanks, in large part, to our oil revenue. We're now investing that revenue in finding cleaner, greener sources of energy to power our way into a brighter future. The Kingdom is building what will be the world's largest green hydrogen facility, with a production target of 50 tonnes a day, aiming to produce 5 million tonnes of clean hydrogen by 2030.

Though the innovation and invention timescale can be frustratingly long, the Kingdom is committed to becoming an innovation superpower in the next two decades. We expect that by 2040, our total expenditure on innovation will reach 2.5% of GDP, more than the G20 average.

We can't do this alone.

At the heart of our commitment to innovation is the desire to build globally collaborative schemes and institutions which, together, will help mankind harness technology to improve lives. Saudi Arabia will invest in bringing scientific talent from other nations to work with our own brightest minds.

KACST (the King Abdulaziz City for Science and Technology) – the Kingdom's leading research and innovation centre – is already working with Cambridge University, Harvard, Berkley and MIT to pool knowledge, resources, information, and ability. As our programme expands in capability, so will our world advance in possibility.

Innovation, investment and people: the Research, Development and Innovation Authority brings all these together. Building on 1,500 years of our region's exceptionally inventive history, the Kingdom of Saudi Arabia will use the fruits of our prosperity to build a better future for everyone, everywhere.

His Excellency Munir Eldesouki - President of King Abdul Aziz City for Science and Technology (KACST)

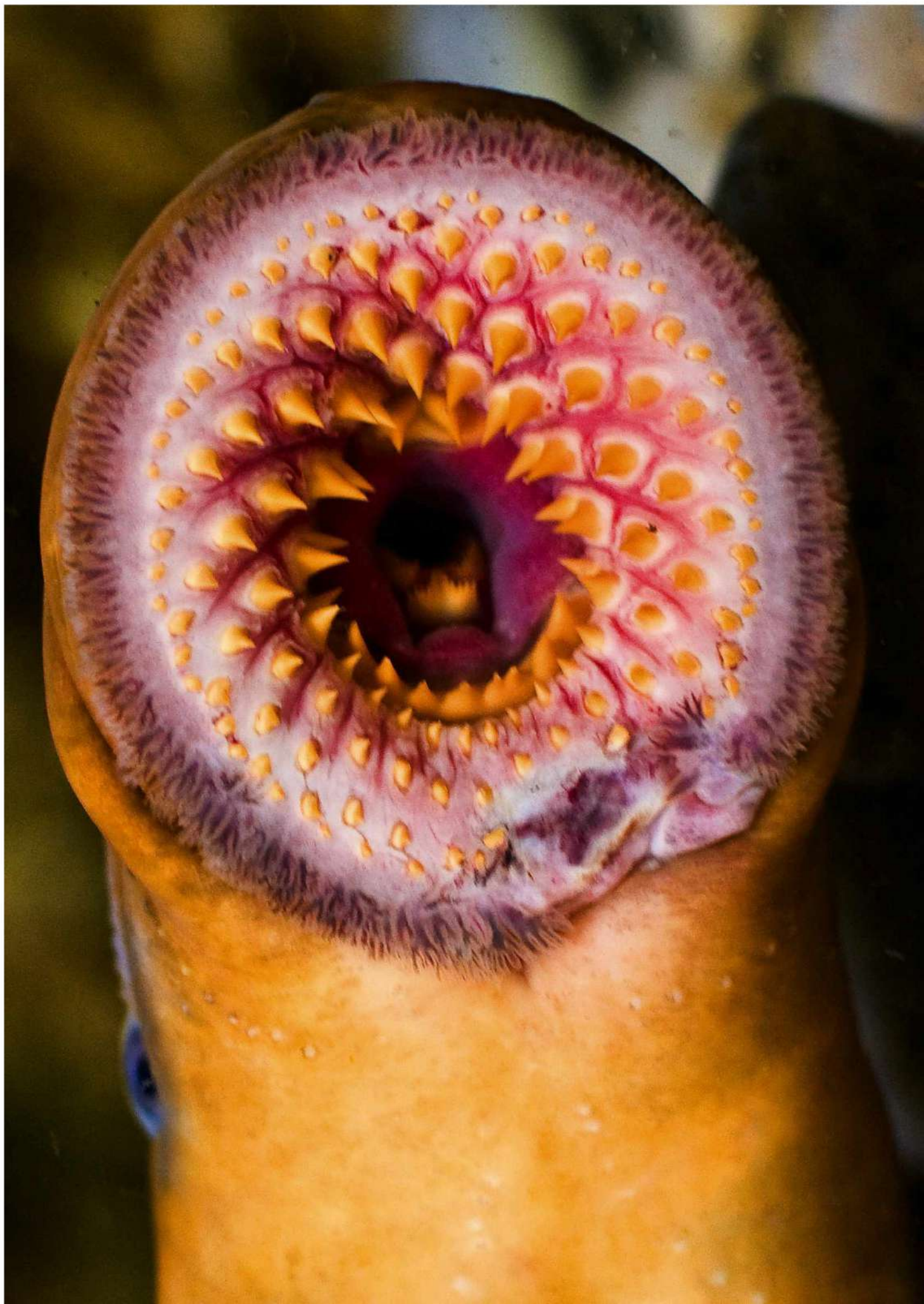
للإنسان نبتكر
INNOVATE FOR HUMANITY

NATURE'S REAL-LIFE VAMPIRES

Count Dracula... Lestat de Lioncourt... Laszlo... all these vampires have got oodles of charisma, natty dress sense and an intriguing backstory. But the problem is, they're fictional. We reckon the animal kingdom can do a lot better. Suck on this...

by DR BRITTNEY G BOROWIEC

ALAMY



Millions of years ago, sometime during the dinosaur era, ancient arthropods experimented with an unusual new diet: blood. Those ancestors of today's mosquitoes, ticks and bedbugs were some of the first, but certainly not the last, to try haematophagy.

Though relatively rare as far as diets go, haematophagy – or blood-feeding – isn't something that evolved once, or even in a small collection of closely-related animals. Haematophagy evolved independently at least 20 times in arthropods alone, as well as in a bunch of worms, some fish, and a few birds and mammals. Despite all this diversity in animal form, each coven of vampires had to tackle similar problems to refine their grisly lifestyle.

THE RED STUFF

A diet as specialised as blood, a renewable but not easily accessible resource, doesn't appear out of nowhere. Mouthparts originally used for piercing or cutting other food, like plants, gave prototype blood-feeders a head start. Many were also fortunate to live in the right place, on and around potential hosts, as scavengers, parasites, or even predators. Supported by these 'pre-adaptations', it was perhaps only a matter of time before some creature struck blood, discovering deep wells of untapped sustenance flowing just beneath the skin, like a Cretaceous-era oil prospector.

But unlike oil, which is the essence of squished and melted carcasses, blood is alive. It's always moving, shuttling essential nutrients, oxygen, and everything else around the body. It's full of electrolytes and protein, making it a better diet than the plant juices and waste that 'pre-blood-feeders' would have sustained themselves on.

The nutritional benefit of blood can be clearly seen in lampreys, a group of primitive, jawless fishes with hook-adorned mouths. Lamprey species can be divided into two groups: parasitic, which feed on fish blood and flesh as juveniles, and non-

TOP LEFT
Blood-feeding stomachs can become full and swollen

BOTTOM LEFT
Parasitic lampreys attach onto their prey and use their sharp mouthparts to pierce the skin

parasitic, which don't feed on blood.

"Non-parasitic lampreys are pretty much indistinguishable from parasitic lampreys as larvae, but the two types 'part ways' during metamorphosis [into juveniles]," says Dr Margaret Docker, an expert in lamprey biology at the University of Manitoba, Canada. Once mature, non-parasitic lampreys are "quite small… much smaller than parasitic lampreys, and even smaller than the largest larvae, since they shrink during metamorphosis." This suggests that the nutritional benefits of blood could help the parasitic lampreys grow larger than their non-parasitic kin.

Another example of the health benefits of 'liquid red meat' comes from vampire moths, some of which feed on humans, and from whom blood-feeding has a clear sexual divide. The male goes through the trouble of blood-feeding, and passes on the extra sodium obtained from his blood feast to his mate as a nutritional child support.

The roles are reversed in mosquitoes, with only the females supping on the red stuff. "Female mosquitoes need a blood meal to develop eggs," says Dr Ben Matthews, a mosquito expert at the University of British Columbia, Canada. This is because eggs take a lot of resources to nurture, and the protein and iron gained from blood meals are essential for proper egg production.

Male mosquitoes will drink small amounts of blood in a laboratory setting, but die a few days later as blood is toxic to them.

A DANGEROUS DROP

Consuming large amounts of blood is dangerous, and adapting to this extreme diet poses special challenges. The most straightforward challenge is that a full belly (and blood-feeding stomachs get *very* full) is heavy, and difficult to move around. No one likes a freeloader, and swollen blood-feeders are at a high risk of counterattacks from their hosts.

The unique composition of blood itself presents problems too. The oxygen-carrying protein haemoglobin accounts for roughly 12 to 20 per cent of human blood by weight, and it's toxic in large amounts.

Haemoglobin is named after its haem structures, rings of carbon and nitrogen built around a single, central iron atom. If you or I decided to start guzzling a diet of blood, the haemoglobin would be broken down by our digestive system. This would cause the iron to be released from its protective scaffolding, which is where the problems would begin. The iron would start to foist electrons onto oxygen, generating aggressive molecules called reactive oxygen species. These run amok within a cell, tearing up valuable resources like fats and proteins. Iron also likes to incorporate itself into biological membranes, causing them to rupture and leak.

"EACH COVEN OF VAMPIRES HAD TO TACKLE SIMILAR PROBLEMS TO REFINE THEIR GRISLY LIFESTYLE"

Blood-feeders rely on two strategies to avoid death by haemoglobin overdose. Some stash the haem in pockets made out of special proteins or membranes. Others fuse the haem groups together into large globs called 'haem aggregates'. Both methods reduce the amount of haem in contact with sensitive cellular structures, and therefore lower the risk of haem toxicity. Counteracting haem toxicity is apparently a universal adaptation to haematophagy.

Since haem toxicity is a niche problem that only blood-feeding specialists have, it's an attractive exploit for medical

THE HUMAN BLOOD-DRINKERS

Attitudes towards consuming blood vary widely across cultures and individuals. For many around the world, blood is just 'liquid meat', and as common a cooking ingredient as a cut of steak. For example, variations of blood sausage, a dish where the fluid is cooked down, thickened, and mixed with spices and filler, occur across the Americas, Asia, Europe, and elsewhere. Blood can be stewed, deep-fried, congealed, and occasionally sipped raw.

Beyond blood as 'meat', there is a small but widespread community of sanguinarians, people who collect and consume blood from willing donors to self-medicate chronic fatigue, headaches, and gastrointestinal issues. The blood drinkers are far from edgy goths, and many wish to find more socially acceptable treatments.

Blood-feeding is taboo for many others for religious, cultural, or personal reasons. Both Islam and Judaism prohibit the consumption of blood, and adherents follow specific preparation procedures to remove it from their meat. Contrastingly, many Christian groups consume the metaphorical blood of Christ (wine) during religious services, though whether they also consume blood at dinner is a matter of personal preference.

GETTY IMAGES, SCIENCE PHOTO LIBRARY

"DRAWING BLOOD WITHOUT GETTING SWATTED, SQUISHED, OR THROWN OFF IS JUST THE START OF THE ORDEAL"

interventions against bloodborne parasites, which also have anti-haem defences. For example, the drugs quinine and chloroquine stop the malaria parasite, *Plasmodium*, from making haem aggregates, leading to cell damage and death.

The dangers of drinking blood don't stop at haemoglobin. Plasma, a yellow-tinged fluid that makes up the liquid portion of blood, is about one-quarter of the saltiness of seawater, and handling all that saltiness represents a major physiological challenge. Left unchecked, such high levels of salt ions interfere with biological membranes and proteins critical for survival. To tackle this, when the kissing bug *Rhodnius prolixus* starts sucking, it activates a suite of proteins along its Malpighian tubules, the insect version of a kidney. The proteins pick out useful ions and molecules from the meal, and leave most of the sodium, water and other less valuable constituents of blood to pass out the other end. The system is so effective that the insects will relieve themselves while feeding, leaving ugly brown smears on their host.

SEEK AND SIP

Since their hosts are always moving around, blood-feeders invest a lot of effort into developing their senses to help them locate their prey. For example, mosquitoes use a combination of long- and short-range signals to track their next meal. Sight, smell, heat, humidity, taste, and the ability to sense carbon dioxide, all help mosquitoes to find their prey. Other insects such as bedbugs and fleas sense hosts in a similar way, by detecting movement and body heat.

But mosquitoes are a lot smarter than we get them credit for. Species like *Aedes aegypti*, which prefer human blood, look for specific odour blends that are signatures of humans as opposed to other mammals. Mosquito species that prefer frogs might eavesdrop on frog song to obtain a blood meal, says Matthews.

When it comes to mammals, vampire bats are the only ones that feed entirely on blood, and they have developed a range of adaptations to suit their grisly suppers. Like other bats, vampire bats use echolocation to navigate in darkness. They also seek out the smell of fur and poo, to guide them to a target. Their ridged nose is dotted with heat-sensing pits, to help them home in on blood flowing just beneath the skin of their prey. Unlike other bats, however, vampire bats can jump and run by slingshotting themselves forward with their wings. They'll tend to land and then approach their host from the ground, and their unique way of moving enables them to quickly sneak up on their prey.

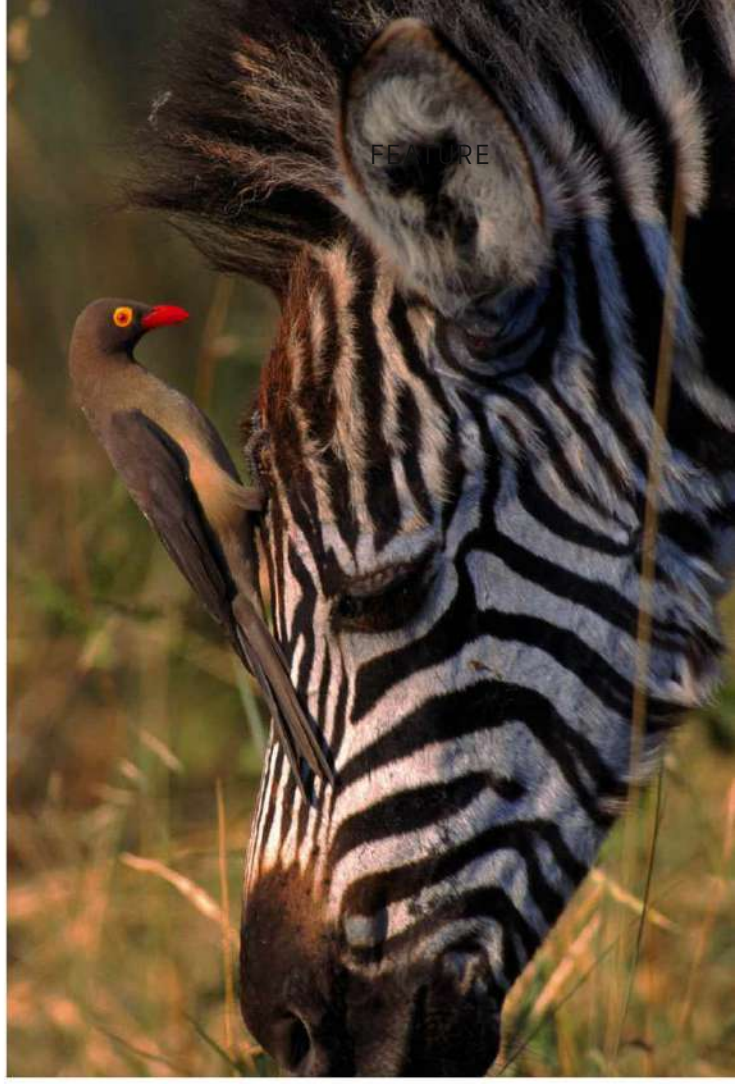
Once a blood-feeding species locates its prey, there's still a lot of work to do. First, they have to get the blood out, ducking out of irritated swipes from their potential host and penetrating thick layers of hide or skin. Generally, there are two ways to approach this: scissors or a syringe. Animals like vampire bats and lampreys make a small cut with razor-sharp teeth or mouthparts and lap up the resulting pool of blood, a mode of feeding called 'telmophagy'. Contrastingly, 'solenophagous' feeders, like mosquitoes and kissing bugs, pierce their prey with tiny mouthparts, and drink directly from the vessels. The latter method is sometimes slower, but is less painful to the host, and therefore stealthier.

Drawing blood without getting swatted, squished, or thrown off is just the start of the ordeal. Next, any worthy blood-feeder has to neutralise the host's defence mechanism against blood loss, known as the haemostatic system, as well as its immune

TOP RIGHT There are three species of vampire bat alive today. This one, the hairy-legged vampire bat, prefers to feed on bird blood

BOTTOM RIGHT Blood-feeding is hard work. The metabolic rate of the kissing bug skyrockets up to 1,600 per cent during feeding compared to non-feeding conditions. For comparison, the ceiling for most humans during extreme exercise is about 300 to 400 per cent

NATUREPL.COM X3, SCIENCE PHOTO LIBRARY



ABOVE When food is scarce, vampire finches on the Darwin and Wolf Islands will peck at the skin and feathers of boobies until blood starts to flow, before guzzling it down

ABOVE RIGHT Oxpeckers will peck parasites off their hosts, but will also pick at existing wounds and open up new ones so they can feed on blood

system. To do this, they rely on a bespoke arsenal of molecules that stop blood clotting, keep vessels open, and anaesthetise the area. The proteins carried in the saliva of arthropods have been particularly well-studied. Among this molecular cocktail is apyrase, a common anti-clotting protein that both prevents and breaks down clots. Tick saliva also contains prostaglandin E2, better known as the labour-inducing dinoprostone. E2 is a triple threat for hosts as it simultaneously opens up blood vessels, prevents clotting, and interferes with the cells of the immune system. Blood-feeding saliva typically contains anaesthetic as well, which affects the host's ability to sense pain and irritation that would reveal the presence of the bloodsucker. Fun fact: the anti-coagulation agent in vampire bat saliva is called 'Draculin', named after Count Dracula himself.

While it's easy to list those obligate blood-feeders, like ticks, most leeches and vampire bats, that must subsist on blood to survive, there is a contingent of lesser-known facultative blood-feeders that only drink the red stuff when it suits them. By occasionally moonlighting as vampires, these blood-feeders supplement their diet with an extra source of nutrients while avoiding the peculiar stresses of the full-blooded lifestyle, like overdosing on haemoglobin.

Several birds are facultative blood-feeders, often hiding their vampiric habits under the guise of pecking at parasites on their hosts' skin. They include the aptly named vampire finch of the Darwin and Wolf Islands in the Galapagos, which sips on the blood of boobies when seeds and fruits are scarce during the dry season. Other birds with a taste for blood include African oxpeckers, which are fond of rhinos and other large ungulates, and the Tristan thrush, which has a taste for penguins.

Obligate blood-feeding evolved multiple times in many unrelated animals, and others occasionally experiment with the diet. While the details of their lifestyles inevitably vary, common themes emerge across many distant lineages. Just like how fictional vampires are marked by their pale skin, nocturnal habits and fangs, real-life vampires share a penchant for brewing up anti-clotting cocktails, packing surgical grade mouthparts, and relying on a variety of other adaptations that enable their extreme diet.

Unfortunately for all these blood-drinkers, beyond a nourishing meal, blood doesn't provide any extra life-giving properties. That sadly remains the reserve of fiction. Fangs for reading... **SF**

by **DR BRITTNEY G BOROWIEC**
(@this_is_brit)
Brittney is a zoologist and science writer based in Ontario, Canada. She studies how fish cope with the challenges of low-oxygen environments.

SFP383

BBC **Science Focus** MAGAZINE

SUBSCRIPTION ORDER FORM

Please complete the order form and send to:
FREEPOST OUR MEDIA *(please write in capitals)*

UK DIRECT DEBIT

☐ Yes, I would like to subscribe to/renew *BBC Science Focus* paying £22.99 every 7 issues – saving 40% *

YOUR DETAILS (ESSENTIAL)**

Title _____ Forename _____
Surname _____
Address _____
_____
_____ Postcode _____
Home phone no _____
Mobile phone no** _____
Email** _____

☐ **I wish to purchase a gift subscription**

GIFT RECIPIENT'S DETAILS (ESSENTIAL)**

Title _____ Forename _____ Surname _____
Address _____
Postcode _____ Home phone no _____
Mobile phone no** _____
Email** _____

Instructions to your bank or building society to pay by Direct Debit DIRECT Debit

To: the Manager (bank/building society)
Address
Postcode
Name(s) of account holder(s)
Bank/building society account number
Branch sort code
Reference number (internal use only)
Originator's identification number

4 4 3 7 7 3

Please pay APS RE Our Media Ltd debits from the account detailed in this instruction subject to the safeguards assured by the Direct Debit Guarantee. I understand that this instruction may remain with APS RE Our Media Ltd and, if so, details will be passed electronically to my bank/ building society.

Signature Date / /

Banks and building societies may not accept Direct Debit mandates from some types of account

KEEP IN TOUCH

***BBC Science Focus Magazine* would love to email you with updates, special offers and promotions. You can unsubscribe at any time. **Please tick here if you would like to receive these** (You can unsubscribe at any time.) ☐

We'd also love to tell you about other offers and promotions from our publisher, Our Media Limited. If you'd rather not be contacted this way please tick here ☐ Post ☐ Phone.Your data will be held by Immediate Media Company Limited (a parent company of Our Media Limited). For information about how we protect your personal data, please see our privacy policy, which can be viewed online at **immediate.co.uk/privacy-policy**

OTHER PAYMENT METHODS

☐ **UK cheque/credit/debit card** – £57.75 for 14 issues, **saving 25%**
☐ **Europe** inc Eire – £92.54 for 14 issues
☐ **Rest of world** – £102.90 for 14 issues
☐ I enclose a cheque made payable to Our Media Ltd for £ _____

Visa ☐ Mastercard ☐ Maestro ☐
☐☐☐☐ ☐☐☐☐ ☐☐☐☐ ☐☐☐☐
Issue no ☐☐ Valid from ☐☐☐☐ Expiry date ☐☐☐☐
Signature _____ Date _____
If credit card address is different, please use the order hotline 03330 162 113

OVERSEAS Please complete the order form and send to: *BBC Science Focus Magazine*, PO Box 3320, 3 Queensbridge, Northampton, NN4 7BF

***Offer ends 9 November 2022.** 40% saving is only available to UK residents paying by Direct Debit. Your subscription will start with the next available issue.

You may photocopy this form

EASY WAYS TO ORDER

ONLINE

buysubscriptions.com/SFP383

PHONE

03330 162 113 †
(please quote SFP383)

POST

FREEPOST IMMEDIATE MEDIA
(please write in capitals)

† UK calls will cost the same as other standard fixed line numbers (starting 01 or 02) and are included as part of any inclusive or free minutes allowances (if offered by your phone tariff). Outside of free call packages, call charges from mobile phones will cost between 3p and 55p per minute. Lines are open Mon to Fri 9am-5pm. *If calling from overseas, please call +44 1604 973 721.*

FSC www.fsc.org MIX Paper from responsible sources FSC® C020508

THE MISSION TO EXPLORE VENUS'S HELL SURFACE
Science Focus
WHY DOES THE UNIVERSE EXIST?
THE SECRET LIFE OF WILD BEES
A ROBOT THAT DOES THE HOUSEWORK FOR YOU
COVID VACCINE BOOSTERS EXPLAINED
GRAB YOUR TINFOIL HAT, INJECTABLE COMPUTER CHIPS ARE HERE!

2021 REVIEW PSYCHEDELICS, MARS, CRISPR AND MORE...
Science Focus
END OF YEAR Q&A
SPECIAL ISSUE
PLUS BRAIN GAMES TEST YOUR KNOWLEDGE WITH OUR CRACKING CHRISTMAS CONUNDRUMS

WHAT YOUR BRAIN DOES TO CREATE REALITY
Science Focus
DARK STARS
How a string of strange discoveries could reveal a cosmos hidden just out of view

EASIEST, QUICKEST WAYS TO GET HEALTHY with MICHAEL MOSLEY
Science Focus
SURVIVING THE NEXT GIANT LEAP
How we'll break through our biological limits to colonise space

BRIAN COX: "I WANT TO LAUNCH BORIS INTO SPACE"
Science Focus
YOUR MYSTERIOUS BRAIN
9 mind-blowing questions about the most incredible object in the Universe

INTRODUCTORY SUBSCRIPTION OFFER!

SAVE 40%

WHEN YOU SUBSCRIBE TO *BBC SCIENCE FOCUS* TODAY*

- **Save 40%** on an annual subscription
- Pay just **£22.99 every 7 issues** by Direct Debit, saving 40%!*
- **Receive every issue** delivered direct to your door with **FREE UK delivery**

~~£5.50~~ **£3.28 PER ISSUE***

BBC
HOW EVOLUTION
Science Focus
The spacecraft that NASA SMASHED INTO AN ASTEROID
Secrets of THE FUNGUS AMONG US
Why positive thinking BOOSTS YOUR PHYSICAL HEALTH
FIRST CONTACT
AN ALIEN SIGNAL IS DISCOVERED. WHAT HAPPENS NEXT?
IN THIS ISSUE
Psychology
Why men lose friends and how it hurts their health
Dark matter
So what if we can't figure out what it actually is?
Environment
What we can do about sewage in our waters

BBC
JAMES WEBB SPACE TELESCOPE THE UNIVERSE SEEN ANEW
Science Focus
EVERYTHING YOU EVER WANTED TO KNOW ABOUT THE MULTIVERSE

FIRST CONTACT

WHAT HAPPENS IF WE EVER DETECT A SIGNAL FROM EXTRATERRESTRIAL INTELLIGENCE?

by DR STUART CLARK

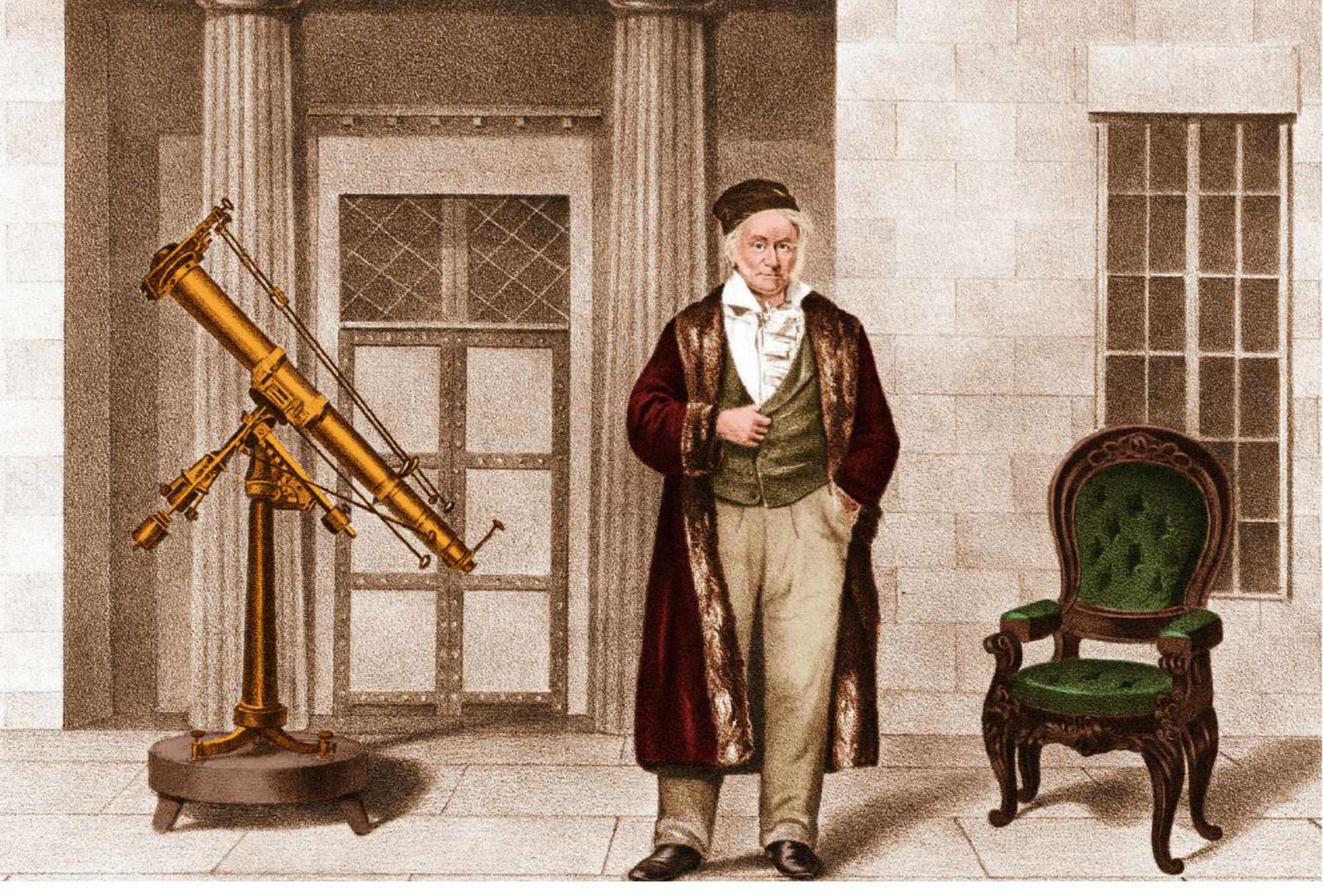
It all seems so simple in the movies. An astronomer – often a maverick – is sitting alone in a radio telescope's control room when a strange signal comes across the speakers. Somehow, the astronomer knows instantly that it's from another world and, a few computer clicks later, the message is decoded and the plot begins to unfold.

But how easy would it be to understand what an extraterrestrial civilisation is saying to us in real life? With a renewed interest in the search for extraterrestrial intelligence (SETI) sweeping across the world, that's the question increasingly being discussed by linguists and other scientists.

"I'm optimistic. I'm quite certain that there's no point in sending a signal that you don't want to be understood. So it'll be understandable," says Sheri Wells-Jensen, associate professor of linguistics at Bowling Green State University, Ohio, and a board member of the Messaging Extraterrestrial Intelligence (METI) organisation. ➤

ILLUSTRATION: ANDY POTTS

BBC TWO
Watch *First Contact* on 6 October 2022. Check *Radio Times* for details.



LEFT German mathematician Carl Friedrich Gauss suggested cutting shapes in forests try to communicate with extraterrestrials living on the Moon

RIGHT The Hat Creek Observatory in California is home to SETI's Allen Telescope Array, which scans the skies in search of radio signals emanating from other civilisations

SCIENCE PHOTO LIBRARY, ALAMY

However, that doesn't mean it'll be *easy* to understand. Without direct access to the beings who wrote the message, it could take years, decades or centuries for us to decode the message. Or we may never decode it all. And here's where things truly take a turn. Based on some researchers' thinking, it may be that never decoding the signal is the best, safest option because we'll have no way of knowing what such a message contains.

It's easy to assume that a message would be benign, perhaps supplying us with information to shortcut centuries of scientific investigation, but some experts now think that the message might have a darker – even dangerous – intention. If so, is our quest to answer the question of are we alone, a case of being careful what we wish for?

A REALISTIC POSSIBILITY

The idea of other life in the Universe stretches back to antiquity. But according to David Dunér, a professor in the history of science and ideas at Lund University, Sweden, it became more realistic to consider the possibility in the 16th and 17th Centuries. This was the time of the Copernican revolution, when Earth was realised to be a planet circling the Sun, and the Sun was accepted to be just another star. This meant that all the other stars in the Universe had the potential to have planets around them as well.

During the 18th and 19th Centuries, scientists began to think of ways we might communicate with extraterrestrials. Thinking that the Moon could be inhabited, German mathematician Carl Friedrich Gauss suggested cutting down large swathes of the Siberian forest to display geometrical shapes. To be certain the signal was not misinterpreted as a natural phenomenon, he suggested that the forest be cut into a geometrical representation of the Pythagorean theorem.

It was in 1960 that American astronomer Frank Drake launched SETI as it exists today. He used the Green Bank Radio Observatory's 26-metre dish to scan for alien radio signals from the nearby stars Tau Ceti and Epsilon Eridani. He didn't receive anything that stood up to scrutiny, but it established the idea of using radio telescopes to search for extraterrestrial radio signals.

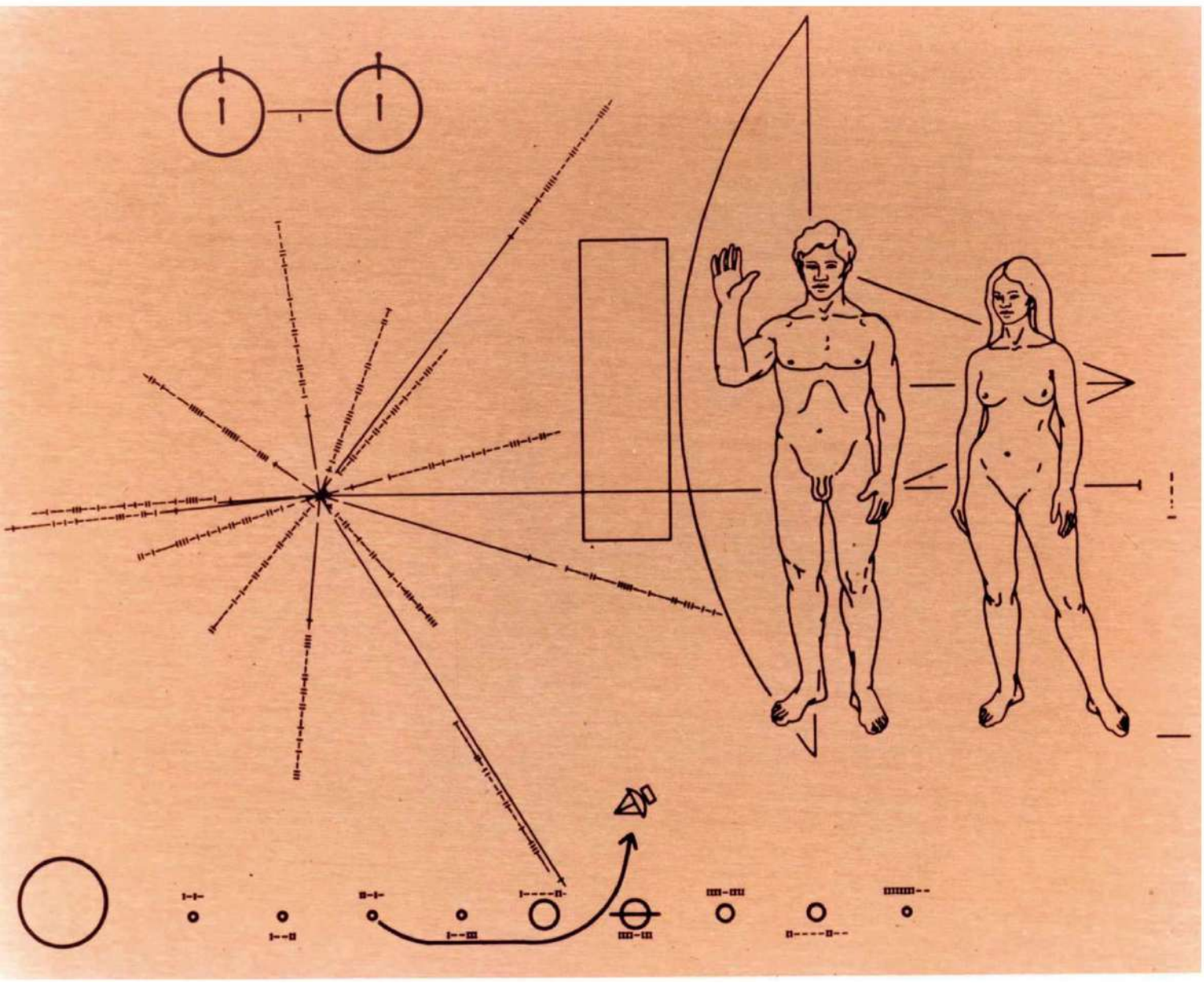
"WITHOUT DIRECT ACCESS TO THE BEINGS WHO WROTE THE MESSAGE, IT COULD TAKE YEARS, DECADES OR EVEN CENTURIES FOR US TO DECODE THE MESSAGE"

While interest in the endeavour has waxed and waned over the years, currently things are looking up. "There's a resurgence in SETI at the moment," says Prof Michael Garrett, director of the Jodrell Bank Centre for Astrophysics and the current chair of the International Academy of Astronautics (IAA) SETI Permanent Committee.

TIMELINE OF DETECTION

The International Academy of Astronautics (IAA) SETI Permanent Committee is the world's only international forum for the discussion of SETI. It meets every year at the International Astronautics Congress. In 1989, it adopted a set of nine principles concerning what happens after the detection of an extraterrestrial signal. Paraphrased, those guidelines say:

1. Anyone who thinks they have detected an extraterrestrial signal should not rush to make a public announcement. Instead they should first seek to verify their conclusion.
2. Once the discoverer has completed their due diligence, other organisations signed up to the guidelines should be informed (and the discoverer's government) so that they too can seek to confirm the discovery.
3. If these partners find that the signal is credible evidence of extraterrestrials, the discoverer should then inform international bodies, including the Central Bureau for Astronomical Telegrams and the UN.
4. The detection should now be communicated promptly, openly and widely. The discoverer should have the privilege of making the first public announcement.



LEFT The plaque on NASA's Pioneer 10 spacecraft displayed information depicting its origin and creators

"INTERSTELLAR COMMUNICATION IS MUCH MORE CHALLENGING BECAUSE WE WON'T SHARE THE SAME BIOLOGY OR THE SAME BRAIN"

He says that a catalyst for this new interest is the investment made by Russian-Israeli venture capitalist Yuri Milner, who studied theoretical physics at Moscow State University. As part of his Breakthrough Initiative programme, Milner has set aside $100m in funding for SETI. Beginning in 2016, Breakthrough Listen started using radio telescopes at the same Green Bank telescope where Drake began the search.

The programme is expected to last for a decade. Although this is primarily an American project, Garrett thinks that it's fostering new interest in Europe and beyond. And with more observatories than ever spending at least some time searching for signals, there has never been a higher possibility of detecting something.

RECEIVED AND... UNDERSTOOD?

In the event that someone does receive a signal, the IAA SETI Permanent Committee has established a protocol for verifying a signal's authenticity before making it public (see box, above). While the protocol is designed to reflect the highest standards of scientific rigour to maintain credibility, the news would almost certainly leak beforehand, especially as the circle

GETTY IMAGES X2

5

Data concerning the detection should be made available to the international scientific community.

6

The source of the signal should be monitored and any additional detections should be distributed for further analysis.

7

The International Telecommunication Union should be notified so that the frequencies on which the signal was detected can be protected.

8

No response to the signal should be sent unless international agreement to do so is reached.

9

An international committee of scientists and other experts should be established as a touchstone for analysis of the signal.

*The full wording of the Declaration of Principles Concerning Activities Following The Detection Of Extraterrestrial Intelligence can be found at **iaaseti.org**.*

of people in the know widens as independent confirmation is sought.

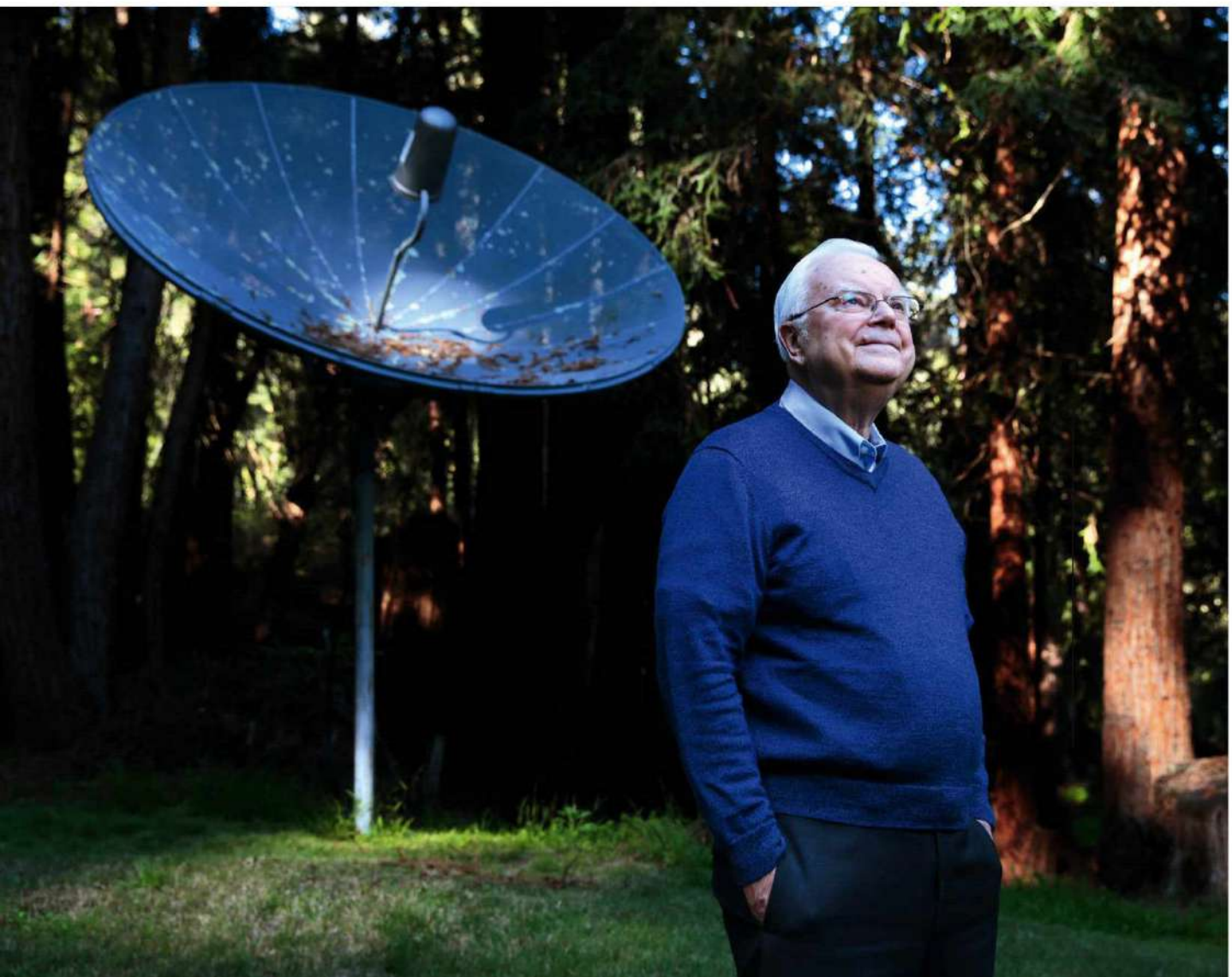
"Even the best intention might be problematic to implement practically," says Yvan Dutil, an independent researcher at SETI and member of the permanent committee.

Yet regardless of how and when the signal is made public, once confirmed as extraterrestrial, the question will be: what does it say? Almost certainly, finding out will be hard. Dunér, who is also a board member of METI, references the difficulty we encountered in deciphering the Egyptian hieroglyphs. The meaning of that ancient writing system was lost to us for around 1,500 years. We only managed to decipher it after Napoleon's troops found the Rosetta Stone in 1799, which famously had the same text inscribed in three languages, one being hieroglyphs. Even so, it took another 20 years before French philologist Jean-François Champollion fully understood the Egyptian writing.

"It was very difficult, even though we had exactly the same brains as the Egyptians of 2000 BC. Interstellar communication is much more challenging because we won't share the same biology or the same brain. We don't even share the same planet," says Dunér.

Without these things in common, communication is much more difficult. This is why some have suggested that mathematics and the laws of physics are the best things to begin a communication with because those will be universal. And if the extraterrestrials are transmitting, then they have clearly developed technology, which means they have an advanced understanding of physics. But just because everywhere in the Universe runs on the same laws of physics, that doesn't mean extraterrestrials will conceive of them in the same way that we do.

"The way we express mathematics is dependent on our culture, our history and also how our earthly brains are constructed. So, they might express mathematics in different ways," says Dunér.



BELOW Frank Drake, the founder of the Search for Extraterrestrial Intelligence

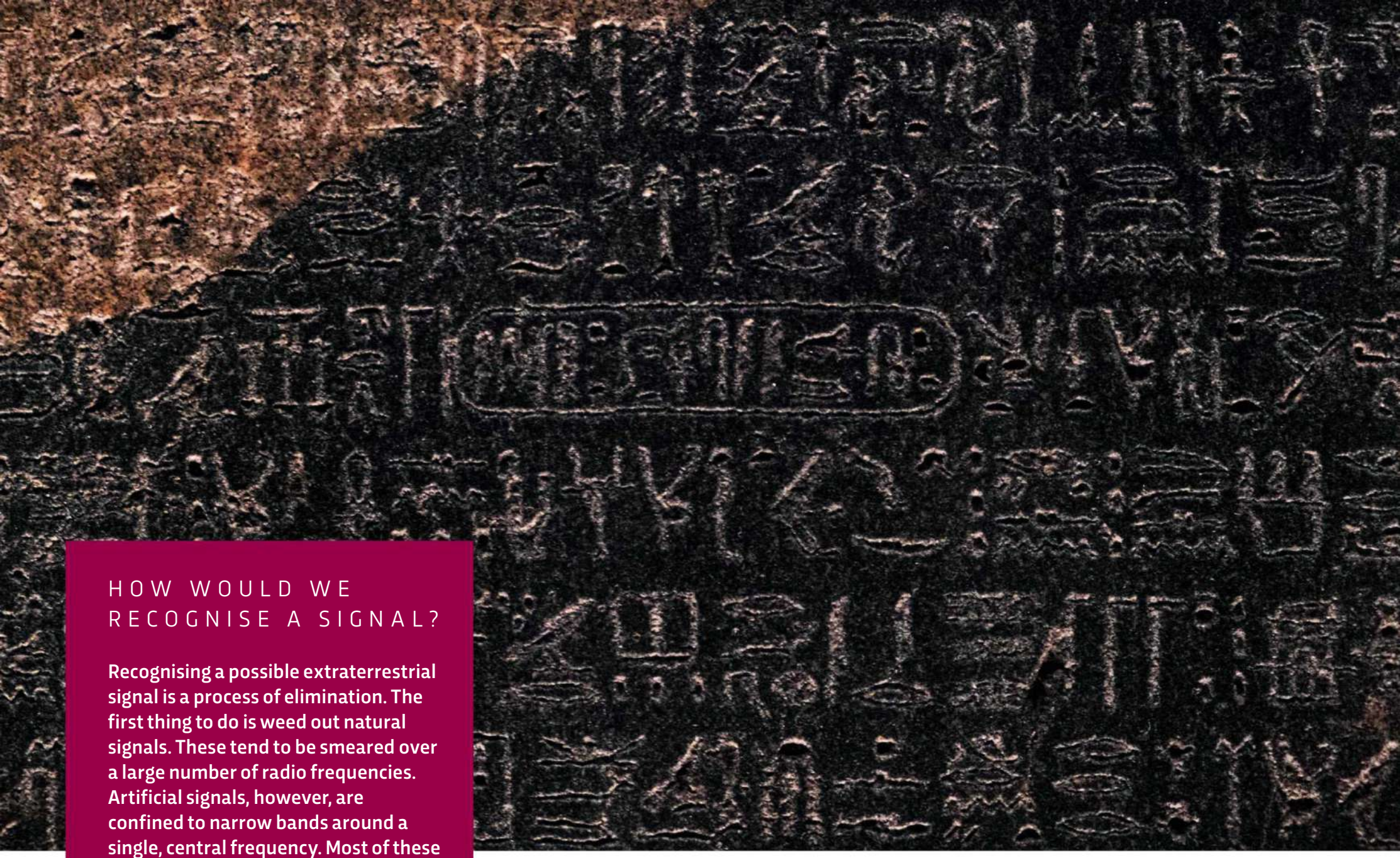
SEND TO ALL

The same goes for the structure of language. For example, it seems entirely reasonable to expect their language to contain the equivalent of nouns, as there will be 'things' in their world. The aliens must also carry out activities, so there will be verbs too. But thinking like this might be a trap.

"The more I'm convinced that I know things, the more danger I'm in intellectually, if I'm wrong," says Wells-Jensen.

In other words, to stand any attempt at deciphering a message, we must not rule anything out. She says that the best way to ensure that happens is to release all of the data, so that anyone who wants to can have a go at deciphering it.

"I have deep confidence in human curiosity. So we'll take that sucker and ➤

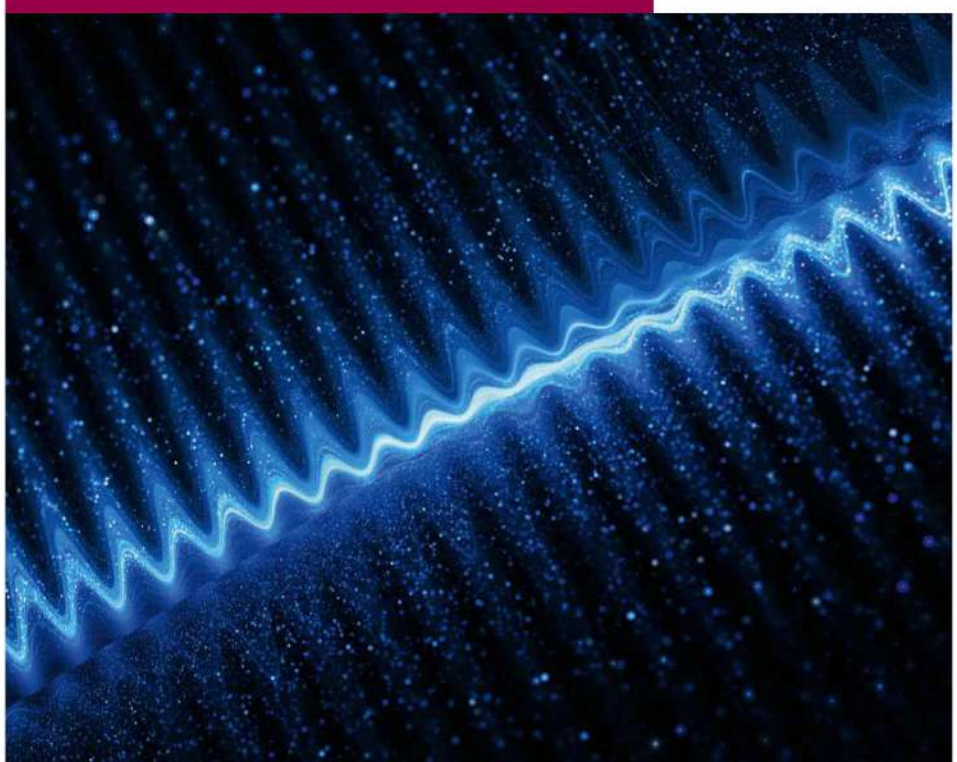


HOW WOULD WE RECOGNISE A SIGNAL?

Recognising a possible extraterrestrial signal is a process of elimination. The first thing to do is weed out natural signals. These tend to be smeared over a large number of radio frequencies. Artificial signals, however, are confined to narrow bands around a single, central frequency. Most of these narrow-band transmissions will be interference from Earth, though. The way to weed those out is to look for traces of movement in the signal. Most terrestrial interference will be from transmitters on Earth, which are not moving relative to the telescope, while celestial signals will appear to move at the rate of the Earth's rotation.

Movement shows up in radio signals through something called the Doppler Effect. This is the same phenomenon that makes the sound of an emergency vehicle's seem to change speed as it approaches and passes you. As the Earth rotates, it will impart a specific Doppler Effect on a celestial source that astronomers can isolate and distinguish from other moving sources such as aircraft and satellites.

ABOVE A close-up view of the hieroglyphics on the Rosetta Stone, which enabled us to decipher the writing system



we'll poke at it and we'll fuss over it until we get it," says Wells-Jensen. So exactly what might extraterrestrials put into such a message? Wells-Jensen hopes for some helpful advice, saying, "It seems like we're not doing so great down here and maybe we could use some input." She subscribes to the idea that any extraterrestrial intelligence signalling across the Galaxy would be older and more advanced than our society, simply because of the technology needed to accurately target a planet from another star system.

Dutil, on the other hand, strikes a note of caution. What if the message is a Trojan horse, he wonders, a subtle attack wrapped up as a message of help? He draws the analogy with misinformation campaigns during wartime, where information is leaked to an enemy to undermine them. "Imagine you're the most advanced civilisation in the Galaxy and you don't want to share the Galaxy," he says.

One scenario he suggests is the dark inversion of Carl Sagan's novel *Contact*. In that story, benign extraterrestrials send humans the plans to build a gigantic machine. On paper, no one can fathom its purpose, but they build it anyway. It turns out to be a device for interstellar travel, bringing us into contact with the aliens. But what if the plans had been totally false, with the machine being all misinformation and nonsense? "Then it's sucked up a huge amount of resources and commitment for nothing," says Dutil. Or worse, the message contains plans for something that will work, but is a weapon to destroy the planet.

Even if the extraterrestrials don't purposely set out to damage us, they may still end up fundamentally changing our intellectual capabilities, especially when it comes to practising science. Imagine the effect of deciphering the signal and finding that it's a 'core dump' of the extraterrestrial's knowledge base, and

LEFT Software engineer Jon Richards points out some of the data collected by the SETI Institute's Allen Telescope Array in California

GETTY IMAGES, SHUTTERSTOCK, SCIENCE PHOTO LIBRARY

that they're scientifically much more advanced than us. Surely a gift? Not necessarily, says Dutil.

Receiving a massive amount of knowledge risks undermining the principal skill of our science: blue-sky thinking. This is because instead of investigating lines of enquiry based on personal interest or current world problems without a fixed idea of where that work might lead, researchers will be working towards a known end-goal. If you know the outcome that you're working towards, says Dutil, then "you could lose the basic scientific skill of understanding how to we ask fundamental questions and investigate."

"EVEN IF WE CAN'T SQUEEZE THE INTENDED MEANING FROM THE MESSAGE, WE'LL SQUEEZE SOME MEANING FROM IT. JUST UNDERSTANDING THAT WE'RE NOT ALONE OUT HERE WOULD BE A REVELATION"

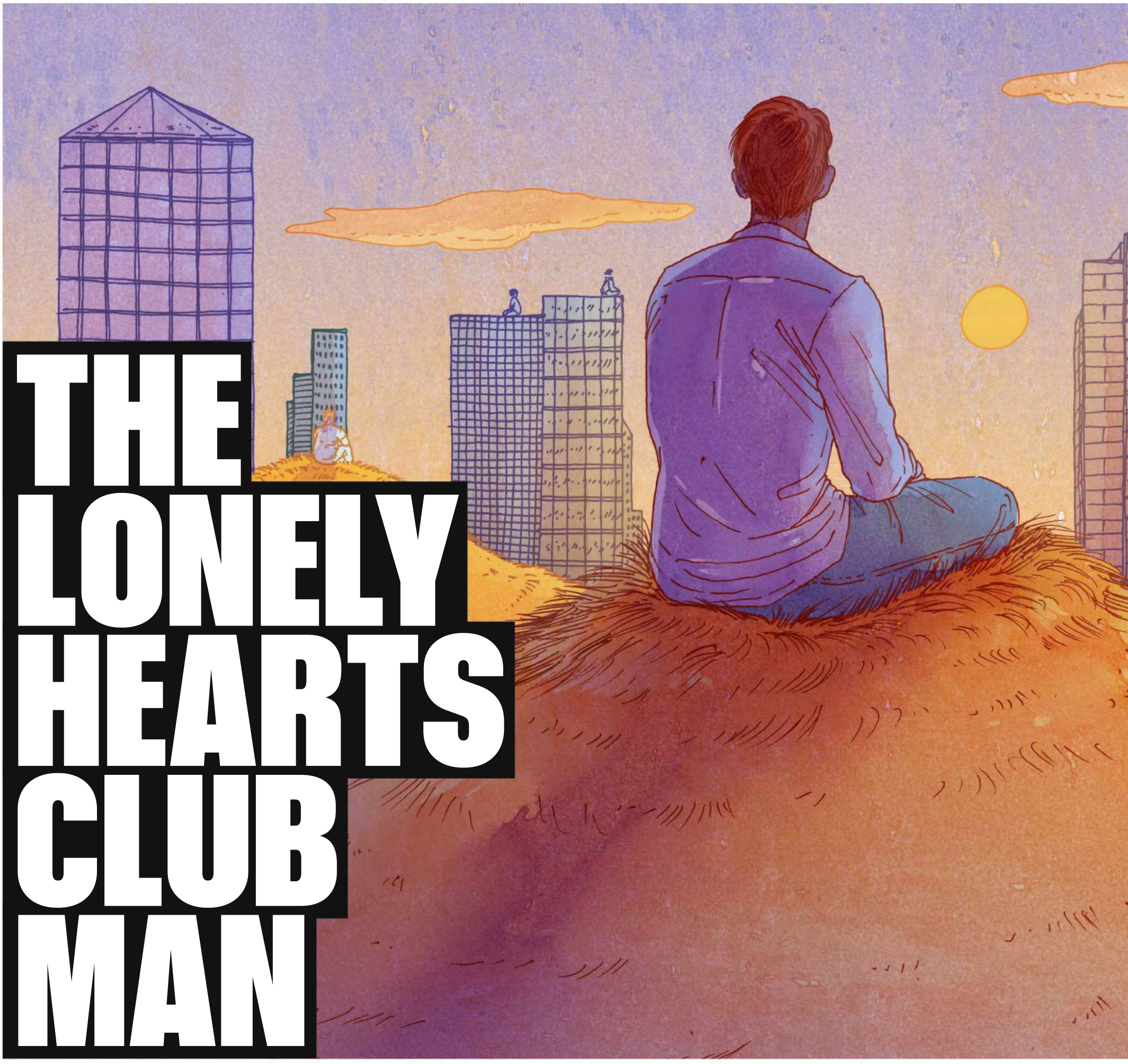
SOMEONE TO TALK TO

These are dark thoughts, and they raise the possibility that perhaps the best outcome would be that we're unable to understand the message. Even if that is the case, Wells-Jensen thinks that we would still gain a lot. "Even if we can't squeeze the intended meaning from the message, we'll squeeze some meaning from it. Just the understanding that we're not alone out here would be a revelation. So even if we don't get what they're trying to tell us, we'll take some lessons from it. And that will be a success."

The detection of an extraterrestrial signal is often described as the greatest discovery that science would ever make. Clearly, it seems that's true for the mere act of detection. It would prove to us once and for all that we're not alone; that the dark realms of space are alive with intelligence looking back at us.

But when it comes to the deciphering that signal, the consequences become much more difficult to navigate. Rather than a straightforward gift, it seems that it would almost certainly be more like opening Pandora's box. When it comes to SETI, be careful what you wish for. **SF**

by **DR STUART CLARK** *(@DrStuClark)*
Stuart is an astronomer and journalist. His latest book is Beneath The Night: How The Stars Shaped The History Of Humankind *(£14.99, Faber).*



THE LONELY HEARTS CLUB MAN

MEN ARE LOSING FRIENDS AND STRUGGLING TO MAKE NEW ONES – AND MISSING OUT ON POWERFUL HEALTH BENEFITS IN THE PROCESS. BUDDY, WHAT'S GOING ON?

by IAN TAYLOR

Back in 2008, a small but very cute study asked people to stand at the bottom of a hill, look up and guess how steep it was. Some people were there alone, others accompanied by friends. The hill, on the campus of the University of Virginia, had an incline of 26°. But to the people who were there with friends, it looked a lot less. Compared with those who turned up on their own, they significantly underestimated the gradient. The feel-good lesson? Everything looks easier when there's a friend by your side.

Yes, mate, the benefits of friendship are profound. Having a strong social circle is associated with a longer life and fewer illnesses. Your

ILLUSTRATION: ELENA BANSH

pals lower your blood pressure and trigger positive chemicals in your brain. People with a strong social network are less stressed, more resilient and more optimistic. They're more likely to be a healthy weight and less likely to suffer cognitive decline. They also enjoy some protection from cancer, heart disease and depression.

But there's one group – a big one – that is missing out on these benefits. Men are lonely. Growing numbers of men are standing at the bottom of that hill, alone and overwhelmed, as surveys point to a recession of social connection among those of us with a Y chromosome.

A YouGov poll in 2019 concluded that one in five men have no close friends, twice as many as women. In 2021, the Survey Center on American Life found that since 1995, the number of American men reporting that they had no close friends jumped from 3 to 15 per cent. In the same research, the number of men saying they had at least six close friends halved from 55 per cent to 27 per cent.

Why do men struggle to make or maintain friendships? And what can we do about it, not just as individuals but on a societal level? Because the sad truth is, an empty social calendar is the least of Billy No-Mates' problems. Loneliness is a health hazard, as dangerous as smoking or alcoholism, according to some research.

A major study by scientists at Brigham Young University in the US found that long-term social isolation can increase a person's

risk of premature death by as much as 32 per cent. For this reason, some have called it the 'shadow pandemic'. It was brought into focus during the COVID-19 lockdowns, when all of us were isolated and friendship became a hot research topic again, but it had spread around the world long before the novel coronavirus had.

"It's a story I've been telling for 30 years," says Prof Niobe Way, of New York University. As a developmental psychologist, Way has spent much of her career interviewing boys and men about their relationships, and how they change over time (documented in her book, *Deep Secrets*). She believes that hyper-masculine ideals are stripping young men of close friendships and the intimacy that goes with them.

"When you speak to boys aged 11, 12 or 13, they have this natural capacity and desire for closeness. And it's not a bromance thing, it's not just wanting to have dudes to hang out with. It's wanting someone they can share their secrets with," she says. "Then you speak to them again around 15 or 16 and you get this stereotype creeping into the responses. They start saying things like, 'Oh sure, I have friends, everyone's my best friend, I don't care, it doesn't matter.'"

MACHO MAN?

Way admits that young men being macho about their friendships is nothing new, but she thinks it's telling that a change occurs in adolescence that – seemingly – frames the way a lot of men form and maintain their relationships all the way through adulthood.

If you've ever watched a sitcom, you know how it goes: men have superficial or transactional relationships with each other and bond by banter as they watch sport or drink beer. Women, in contrast, have deep and emotionally vulnerable conversations marked by shared secrets and interpersonal closeness. The funny thing is, these sitcom stereotypes are borne out by research.

"One of the main things we've shown is that the two sexes are very different in their social style," says Prof Robin Dunbar, an anthropologist at the University of Oxford whose work centres on social bonding. "The girls' social world has been built around personalised relationships. It matters *who* you are, not *what* you are.

"For men, what makes the difference is investing time in doing something together. It might be meeting up for a pint or arranging to climb Ben Nevis. The activity is irrelevant as long as it's a group activity – and that often doesn't involve a lot of conversation. There's a bit of banter but really, the content is close to zero."

The difference between male and female friendship is often characterised as side-by-side versus face-to-face relationships. When men meet their friends, they stand shoulder-to-shoulder: at the bar, at the football ground, fishing at a river. When women meet up, they often sit across a table from each other and talk.

The emotional investment and frequent contact that women prize is not as important for men, Dunbar says. Men can go months without seeing a mate but still consider that person a close friend. Could this superficial approach to friendship explain why men are losing friends and more likely to feel lonely?

"FOR MEN, WHAT MAKES THE DIFFERENCE IS INVESTING TIME IN DOING SOMETHING TOGETHER. IT MIGHT BE MEETING UP FOR A PINT OR ARRANGING TO CLIMB BEN NEVIS"

It's almost certainly a factor, but it's not the only one. Sociological and generational changes also play a part. It was only a few generations ago that, for the majority of people, friends were constants in our lives, like family. People moved less, travelled less, changed jobs less. Today, our mobility – literal and figurative – means that friendships can more easily come and go.

Loneliness and isolation can also happen as a consequence of other things, says Dr Mike Jestico, a psychologist at the University of Leeds who also works with local men's groups in the city. "Homelessness, addiction, breakdown of family home… Men are more likely to experience these than women, leading to isolation," he says.

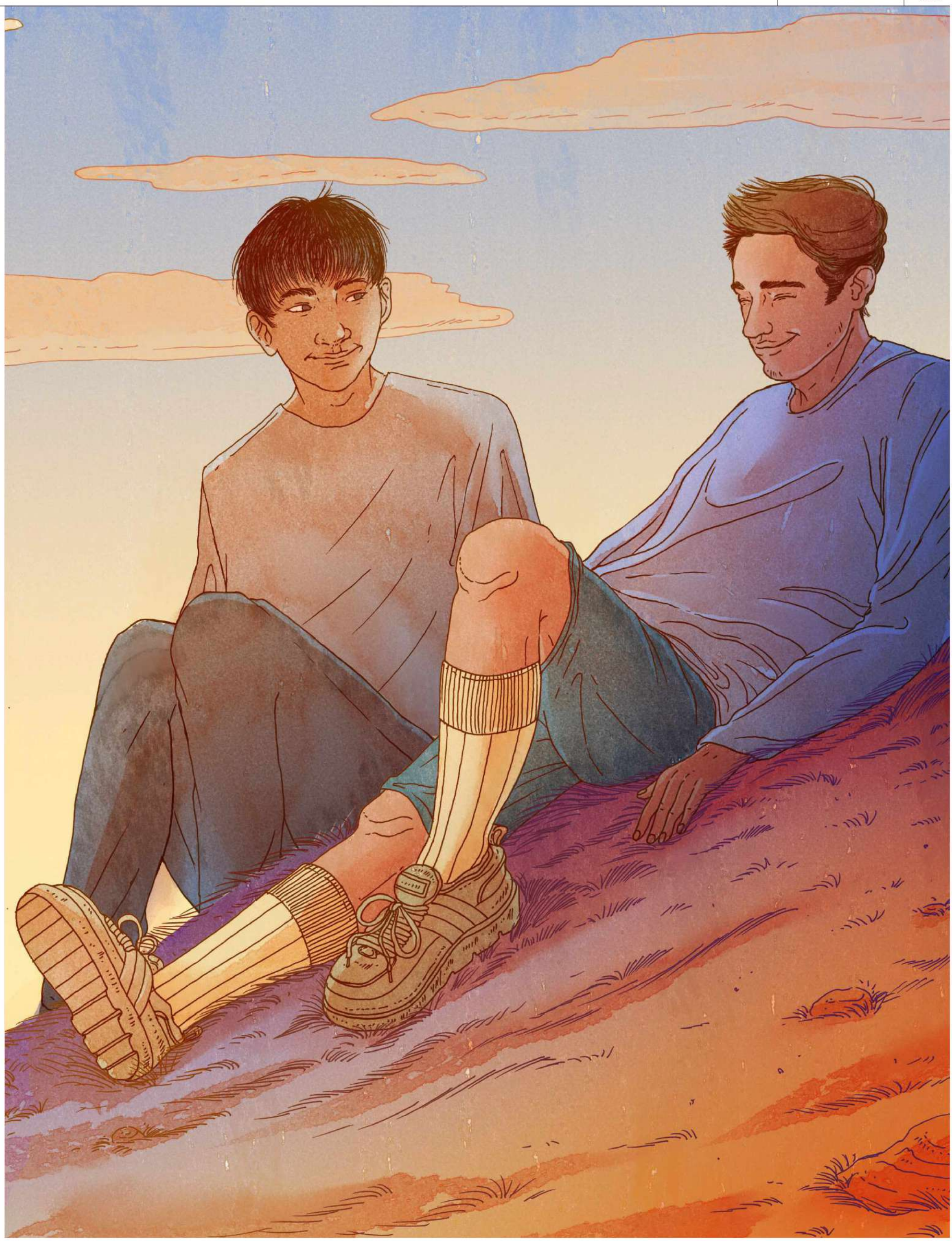
"Isolation is more likely to happen to men with lower incomes, as social experiences tend to cost money. One of the men in my research sang in a social singing group. But when the group moved venues, he couldn't afford the bus fare to travel, thus increasing his isolation."

Jestico says that a kind of 'structural' isolation can also be a factor. Single men are more likely to live alone in high-rise tower blocks, for example, and are less likely to be the primary caregiver of children.

"The bedroom tax meant single men could not afford to live in accommodation with more than one bedroom and moved into smaller accommodation with some high-rise flats in Leeds having 75 to 80 per cent male residents in 2016.

BELOW Prof Niobe Way has spent much of her career interviewing men and boys about their relationships

GETTY IMAGES ILLUSTRATION: ELENA BANSH



BUDDY SYSTEMS

SCIENTIFIC WAYS TO MAKE FRIENDS AND INFLUENCE YOUR LONG-TERM HEALTH

ASK QUESTIONS

Harvard neuroscientists found that talking about yourself triggers neural reward systems, just like food or sex do. So make your new acquaintance feel good by asking them about themselves and listening.

PUT THE TIME IN

According to a study at the University of Kansas, it takes 200 hours of socialising for somebody to become a close friend. That includes around 50 hours to upgrade from an acquaintance to a casual friend.

FIND COMMON GROUND

No surprise here: you need a few things in common. Anthropologist Prof Robin Dunbar's seven pillars of friendship include things like world view (religion, morals or ethics), educational trajectories, as well as shared hobbies or tastes in music or humour.

GO TO THE SHED

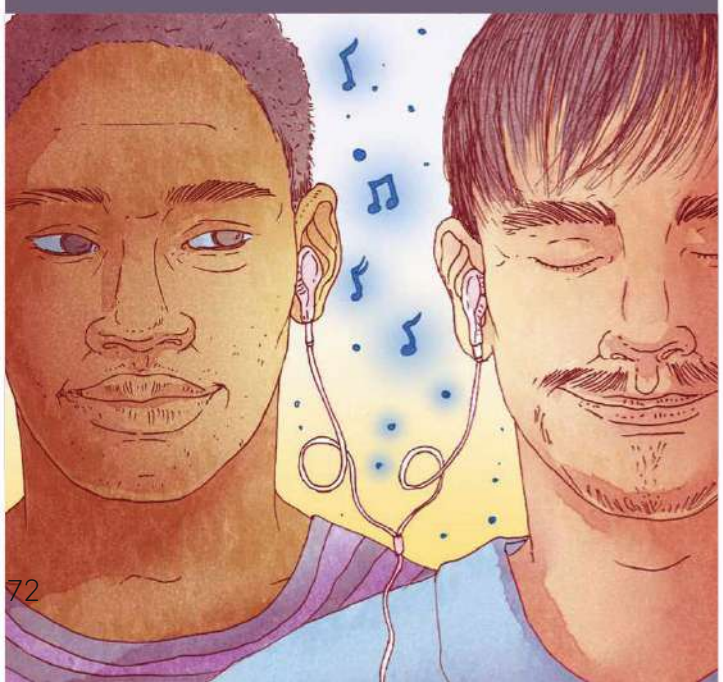
Psychologist Dr Mike Jestico recommends seeking out local community groups, walking clubs or **menssheds.org.uk**. The latter is a network of community spaces where men are invited to connect and converse while doing things like crafts and DIY.

CHECK IN

Don't underestimate the power of a quick call or message to a friend you haven't seen or spoken to in a while. New research from the University of Pittsburgh found that check-ins like this are more deeply appreciated than most of us realise.

SING YOUR HEART OUT

Joining a club or group is one of the surefire ways to enhance your social circle, but if all else fails, join a choir. Dunbar says that singing has a seemingly unique ice-breaking effect, and people who sing together bond remarkably quickly.



"One of my participants, who did not live with his children's mother, was moved 15 miles from his two-bedroom flat to an affordable one-bedroom flat. This meant he lived further from his friends and children, who were much less likely to stay with him as he only had one bedroom."

There's more too. Throw in working from home, the closure of pubs, declining engagement in religious activities or social clubs, not to mention smartphone addiction and so-called social media, and perhaps the statistics on men's shrinking friendship circles aren't that surprising after all.

ABOVE According to anthropologist Prof Robin Dunbar, men can bond by sitting quietly together

PLANS MAKE THE MAN

Another important factor is, of course, that men are a bit useless. When it comes to making plans or staying in contact with friends, men are socially lazy. This appears to be especially true in middle age when something strange happens with men's friendships. At this age, men don't appear to be lonely, on the surface.

"Data including men and women has often found a U-shaped relationship, where teenagers and the oldest people in society are the loneliest," says John Ratcliffe, a researcher at the Centre of Loneliness Studies at Sheffield Hallam University. "That said, the highest suicide rates are in single men in their 40s and 50s."

Men show a stronger link between marital status and loneliness than women, Ratcliffe says. Which is to say, unmarried women are less lonely than unmarried men. "I would link this statistical trend to a greater 'reliance' on partners for intimacy in men, and a greater ideation of the family role. For men who don't have a partner, loneliness can be particularly severe."

But even for men who are coupled up, middle age is tricky territory. At this stage of life, guys might drop out of the five-a-side team, or family commitments keep them from the after-work drinks or the hobbies they once had more time for. They may have fewer peers in the workplace, and the friends they see on a regular basis may not be particularly close ones.

"Because males are socially lazy, what tends to happen is the wife ends up driving the social environment for the household," says Dunbar. "The guys end up becoming friends with the partners of their wives' friends – because they're there."

GETTY IMAGES X2 ILLUSTRATION: ELENA BANSH

"BECAUSE MALES ARE SOCIALLY LAZY, WHAT TENDS TO HAPPEN IS THE WIFE ENDS UP DRIVING THE SOCIAL ENVIRONMENT FOR THE HOUSEHOLD"

Men's reliance on their partners can also lead to further problems. For one, it places a lot of pressure on the women (in heterosexual relationships, at least), and if the relationship breaks down or the man is widowed, it can leave him abruptly isolated. "When you have a divorce or you're widowed, suddenly half your social world vanishes overnight," Dunbar says.

So what's to be done? Way says that it has to start with boys, addressing the culture of masculinity that young men grow up in.

"The lack of friendships amongst men is just a symptom of the bigger problem. I feel like journalists – and social scientists – bring the microscope in too much. And so we only focus on this specific symptom," she says. "If you bring up the microscope just a tiny bit, you begin to see this is just a symptom. Because boys do have and want close friendships."

Way believes we should try to foster boys' latent caring and emotional side. Being socially and emotionally intelligent is not a female trait, she says: it's a human one. "We don't have to teach it, we just have to nurture it."

Dunbar is more cautious about dismantling the way boys and men socialise, arguing that you see the same behaviours in monkeys and apes that you see at nurseries, schools and workplaces. He pictures two Mediterranean men sitting outside a cafe in the sunshine. They smoke cigarettes, drink coffee and stay there for hours saying almost nothing to one another.

"Don't knock it!" he says. "This is boys bonding. Girls would never do that because they would want to talk to each other, but for boys you can sit down in complete silence and still build a relationship, providing there's an activity or some kind of focus."

For Dunbar, finding a shared activity is key, and his advice to lonely men is to start there, by finding a club or something you're interested in. "Dancing, singing, playing rugby or tennis, climbing hills – you name it. They all trigger endorphins. And when you do it with other people, you end up bonding. It's a very powerful mechanism," he says.

Volunteering has a similar effect, whether it's something charitable, or getting involved in your children's sports teams, or local political or environmental movements. In 2020, Dunbar and his colleagues published a pan-European study in which they found that your future risk of depression is lower if you take part in three voluntary activities.

This taps into another stereotype about men: as much as we want to be loved, we also want to be useful. "In my research, a sense of 'worth' is often central to non-loneliness in men," says Ratcliffe. "That is, feeling accepted, respected, loved, and/or admired. It also appeared related to neurological stimulation – the idea of being positively occupied."

Ratcliffe believes that building self-worth in young boys and lonely men alike is important to undo the pandemic of disconnection. At the same time, he wants to deconstruct masculine expectations that say you have to be invulnerable, that compel men to say they're okay when they're not, or that they're not lonely when they are.

Part of this is realising that you're not alone in feeling alone, adds Way. "We have to normalise it so that people don't somehow think they're weird, but that it's actually that culture has made it very hard for you to find meaningful relationships."

Want to make a start? Way suggests sending this article to men you know, whether or not you think they are lonely. "Lots of men need a jumping-off point to start having conversations with other men about this kind of stuff. Send them the article and just ask them: 'What do you think?'" It could be the start of a beautiful friendship. **SF**

BELOW Voluntary work can offer a sense of worth, and can help people to build friendships

by **IAN TAYLOR**
(@IanStean)
Ian is a freelance writer and editor.

BBC Science Focus Magazine Reader Survey

Let us know what you think **for a chance to win a £250 Amazon Voucher!**

Would you like to have your say in the development of *BBC Science Focus Magazine*?

Every two years, we carry out research on behalf of BBC Studios that invites readers to share their views about this magazine and other BBC Studios titles.

This essential research is used by BBC Studios and the editors to shape future content and strategy for the magazines. We would really appreciate your time to help us with this research.

To take part in the research and be entered into a prize draw to win a £250 Amazon Voucher, please visit:

bbcstudios.com/survey

The survey will take less than 10 minutes and is being conducted according to Market Research Society guidelines. All of your responses are completely confidential.

Terms and conditions: The prize is one £250 Amazon Voucher. One winner will be drawn at random after the closing date at 23.59 on 31st December 2022. Open to all residents of the UK and the Channel Islands aged 18 years or over except employees of BBC Studios or the BBC, their contractors, members of their families and anyone connected with this prize draw. Only one entry permitted per person. There is no cash alternative and the prize is not transferable. No purchase necessary. The prize draw is subject to the laws of England and Wales. Promoter: BBC Studios Limited, Television Centre, 101 Wood Lane, London W12 7FA. Your data will be used for the purposes of administration of this prize draw and in accordance with BBC Studios's Privacy Policy (www.bbcstudios.com/privacy). Where consent has been provided, BBC Studios may send email marketing messages from which you may unsubscribe at any time.

BBC Science Focus MAGAZINE

Q&A

YOUR QUESTIONS ANSWERED

... HOW SOON AFTER GETTING COVID-19 CAN YOU CATCH IT AGAIN?
... HOW IS COLOUR ADDED TO JWST IMAGES?
... WHAT IS WHITE, PINK AND BROWN NOISE?
... DO PAINKILLERS WORK DIFFERENTLY FOR DIFFERENT PEOPLE?
... CAN CONTACT LENSES GET STUCK BEHIND YOUR EYE?
... HOW MUCH ENERGY DOES A SMART METER USE?
... CAN YOU MAKE A FUNCTIONAL CANDLE FROM EARWAX?
... WHAT IS THE MAILLARD REACTION?
... OWLS VS LARKS: WHEN IS THE BEST TIME OF DAY TO EXERCISE FOR SLEEP?
... WHY DOES NASAL AND EAR HAIR BECOME MORE PROMINENT AS YOU AGE?

Email your questions to

questions@sciencefocus.com

or submit on Twitter

@sciencefocus

OUR EXPERTS

DR HELEN PILCHER
Biologist and science writer

PETE LAWRENCE
Astronomy expert

DR NISH MANEK
GP and medical expert

DR ALASTAIR GUNN
Astrophysics lecturer

DR EMMA DAVIES
Science writer

DR JEREMY ROSSMAN
Infectious disease expert

PROF ALICE GREGORY
Psychology and sleep expert

HAYLEY BENNETT
Science writer

LUIS VILLAZON
Science and tech writer

PROF PETER BENTLEY
Computer scientist

DR CLAIRE ASHER
Science journalist

ILLUSTRATION: DANIEL BRIGHT

ANNA ROHAN, HASTINGS

HOW DO CATS KNOW WHEN IT'S ABOUT TO RAIN?

In days gone by, sailors thought ships' cats could predict the weather. Perkiness indicated fair conditions. Sneezing foretold light rain, while weird behaviours, like licking their fur in the wrong direction, were suggestive of storms. Some even thought that cats caused the storms via magic stored in their tails. Although science has yet to disprove the latter, some modern-day owners do notice that their felines act 'oddly' before a downpour. It's thought the cats' inner ears are sensitive to the atmospheric pressure reduction that precedes precipitation (when water falls from the sky), but a word of caution. With their famous mood swings, how can you ever really know if your cat is acting oddly?! ***HP***

GEOFF WINSTANLEY, BLANDFORD FORUM

DO PAINKILLERS WORK DIFFERENTLY FOR DIFFERENT PEOPLE?

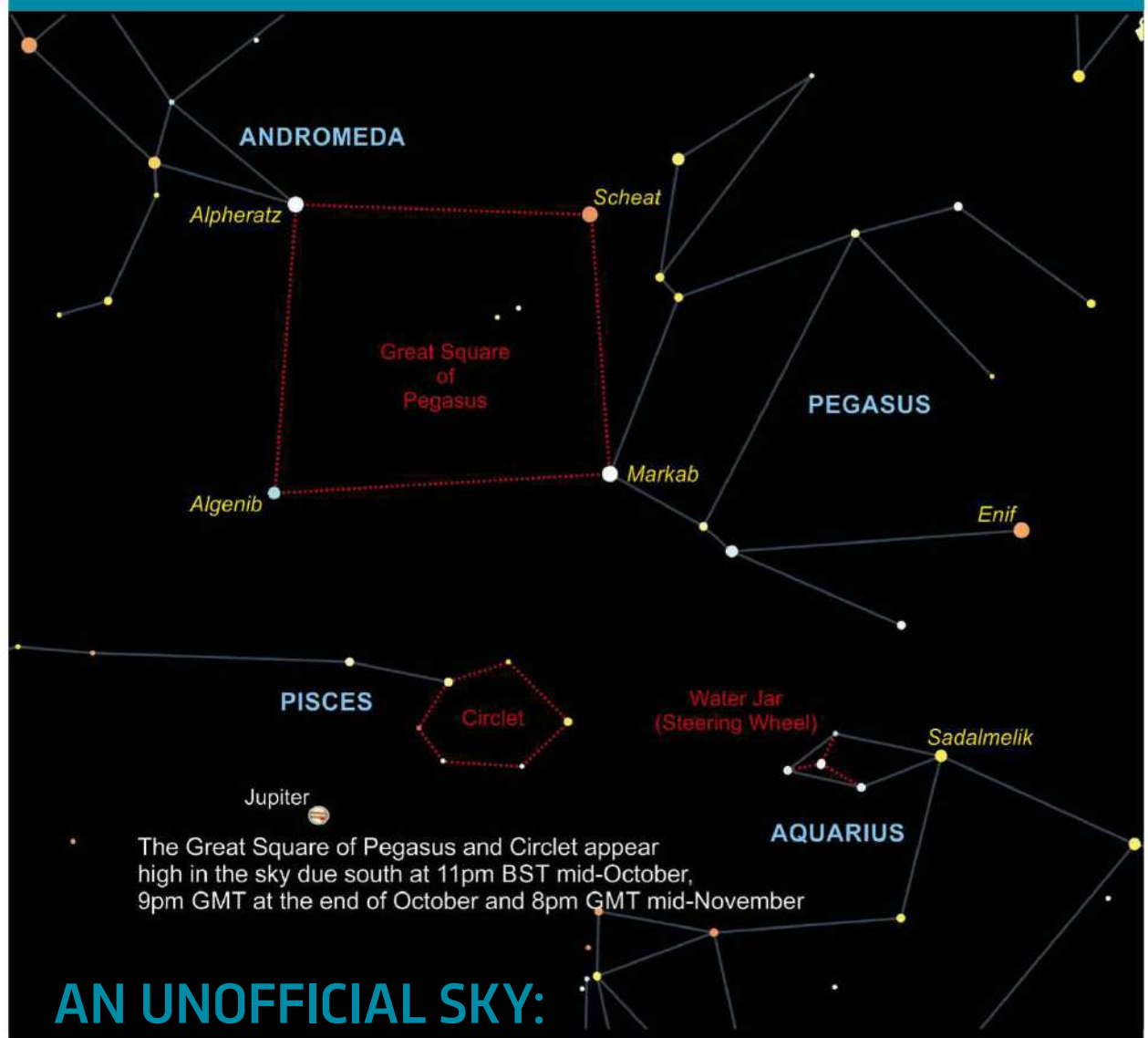
In short – yes, it is thought that there is some individual variation in the response to a particular painkiller. But pain is a complex perception. Sensation is influenced by so many factors, including variation in the type of pain, genetic factors, stress-related physiological responses, socio-cultural influences, our prior experience, emotional state, and by the context it occurs. So it is difficult to attribute our response to a painkiller to something as simple as painkiller receptors alone, but these are likely to play a part. ***NM***

KAY HUGHES, VIA EMAIL

HOW MUCH ENERGY DOES A SMART METER USE?

There are several parts of a smart meter that use electricity. They have little computers and communications circuits to let them talk to each other and the energy company, which use minimal energy. Your gas meter circuits are powered by a battery, which needs replacing every 10 years or so. Your electricity meter powers itself from the electricity supply, but doesn't charge you for its own energy. You're also given an in-home display to see your usage. In a year, it uses less than 1kW energy, costing about £1. But it's optional – you can also unplug it. ***PB***

ASTRONOMY FOR BEGINNERS



AN UNOFFICIAL SKY: A GUIDE TO ASTERISMS

The sky is divided into 88 constellations of varying sizes. The areas are defined and controlled by a body known as the International Astronomical Union (IAU). The stars in each constellation create patterns representing creatures, both real and mythological, as well as inanimate objects.

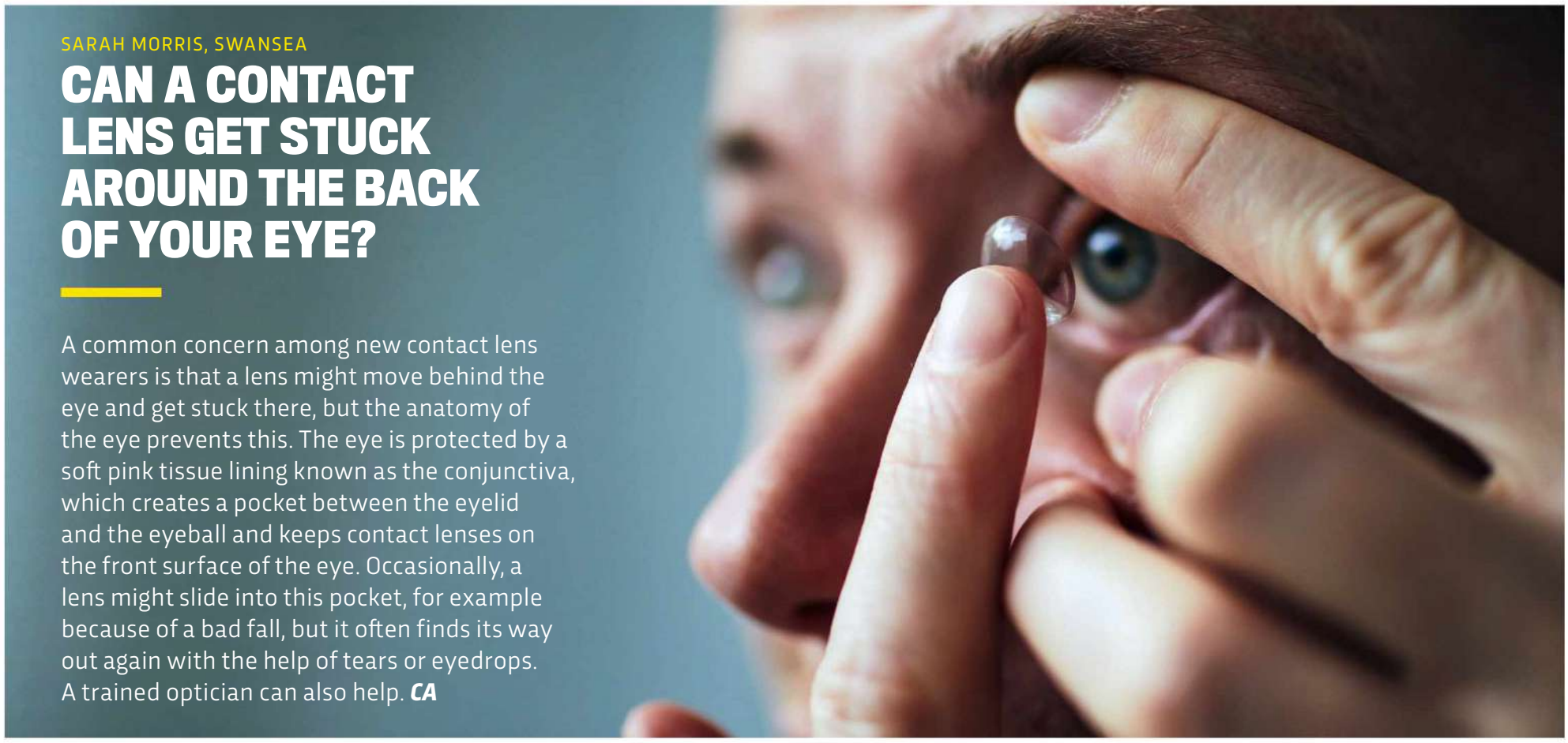
Asterisms are unofficial patterns designed to help navigate the night sky. Anyone can suggest an asterism, but in order for it to stick, it has to become popular. Asterisms can contain stars from multiple or single constellations, and they can be huge or tiny.

Many asterisms are on view at this time of year. The Summer Triangle is a bold favourite formed from three bright stars from different constellations; Vega in Lyra the Lyre, Deneb in Cygnus the Swan and Altair in Aquila the Eagle. This large pattern is visible high, just west (right) of south at 9pm BST on 1 October, 8pm BST mid-month and 6pm GMT at the end of October.

The Summer Triangle is followed across the sky by the Great Square of Pegasus. This is another asterism formed using stars from different constellations, as technically the star Alpheratz in the northeast (upper-left) corner belongs to Andromeda the Chained Princess. The stars forming the square are middle-bright and the roughly square pattern has sides approximately 1.2 to 1.5 times the width of your clenched fist at arm's length. Look immediately below the Great Square to find another geometric shape, the Circlet asterism; bright Jupiter currently sits southeast (below-left) of it. This is formed from stars within Pisces the Fish and although not particularly bright, it is distinctive in a dark sky.

Right of the Circlet is a group of four stars within Aquarius the Water Bearer, one at the centre and three spaced at 120° intervals around it. This is the Water Jar asterism, sometimes known as the Steering Wheel. *PL*

GETTY IMAGES X2 ILLUSTRATIONS: PETE LAWRENCE, DANIEL BRIGHT



SARAH MORRIS, SWANSEA

CAN A CONTACT LENS GET STUCK AROUND THE BACK OF YOUR EYE?

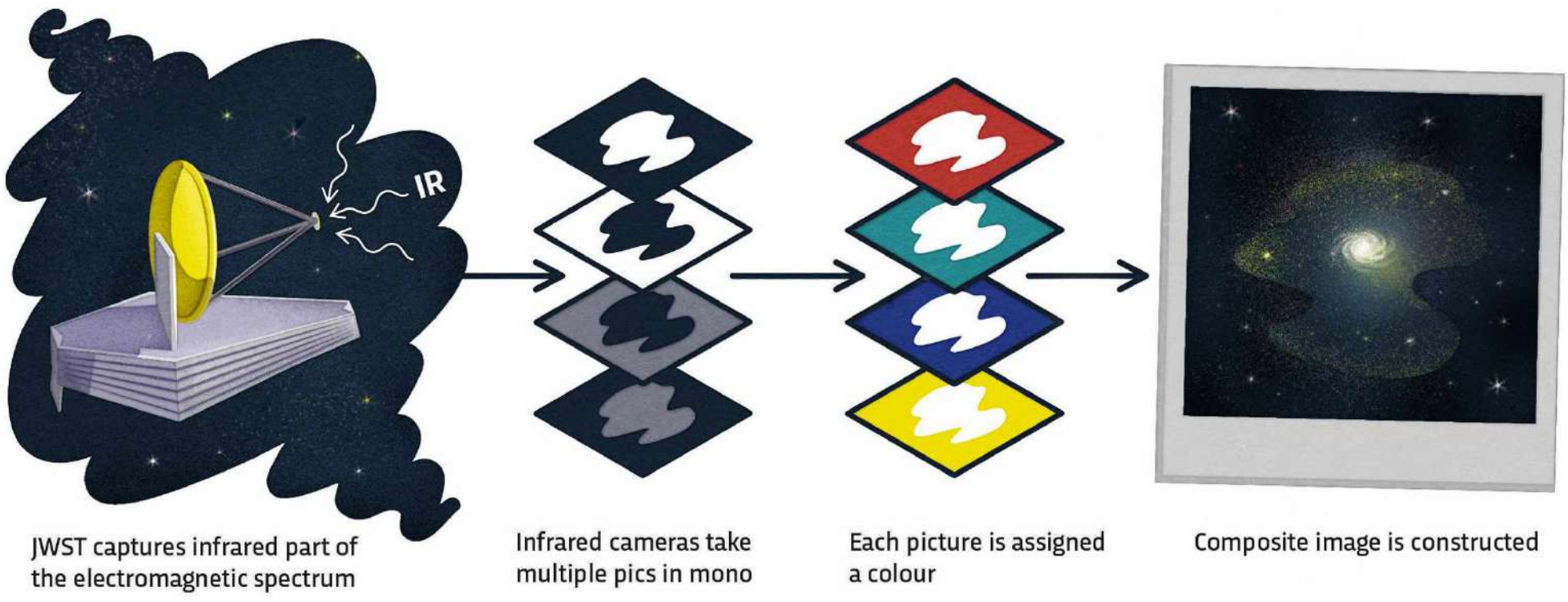
A common concern among new contact lens wearers is that a lens might move behind the eye and get stuck there, but the anatomy of the eye prevents this. The eye is protected by a soft pink tissue lining known as the conjunctiva, which creates a pocket between the eyelid and the eyeball and keeps contact lenses on the front surface of the eye. Occasionally, a lens might slide into this pocket, for example because of a bad fall, but it often finds its way out again with the help of tears or eyedrops. A trained optician can also help. ***CA***

BENJAMIN MARSH, VIA EMAIL

HOW IS COLOUR ADDED TO THE JWST IMAGES?

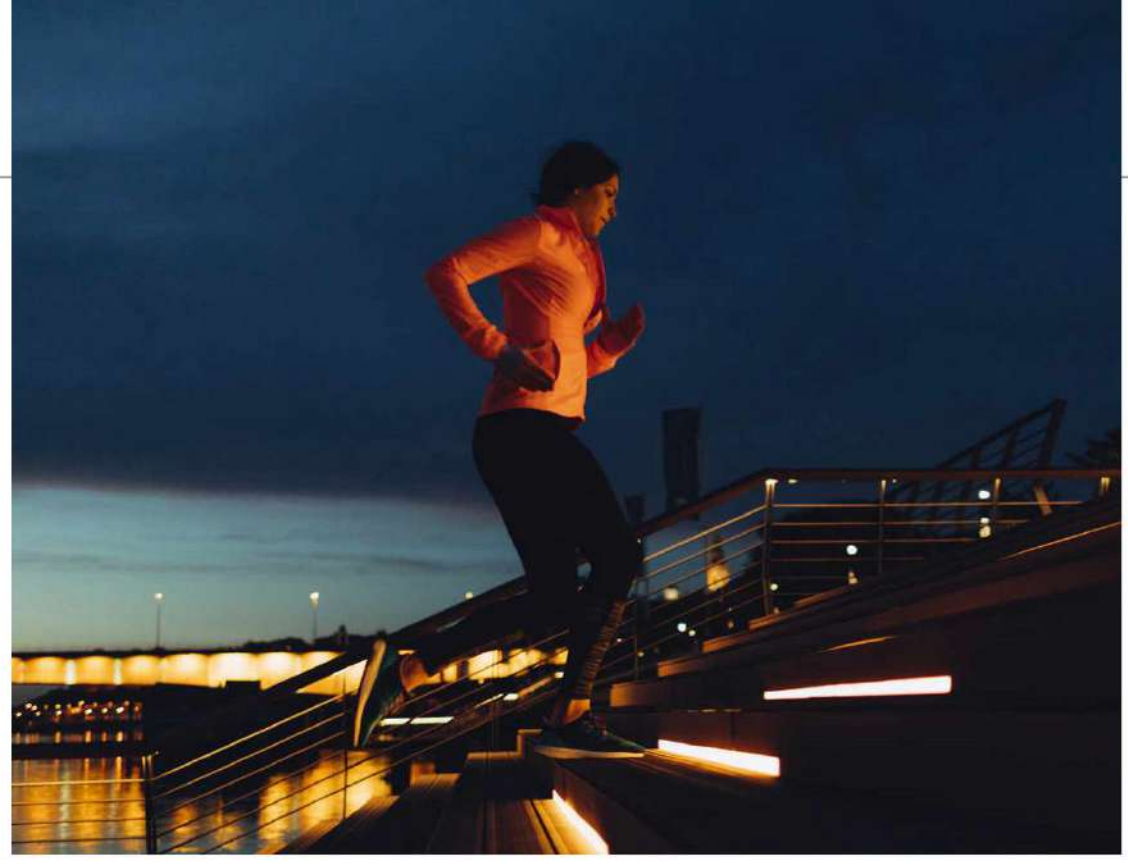
This July we were treated to the first spectacular images taken with NASA's James Webb Space Telescope (JWST). But JWST is an infrared (IR) telescope, meaning that it is not seeing what the human eye sees. In fact, JWST is detecting what we feel as 'heat', just like night-vision goggles, and the JWST images are just a representation of its view in optical light. So, the colours in the JWST image are not real – they are not what your eye would see.

The colours, however, do represent something real — the variation in brightness with wavelength. Essentially, the JWST takes up to 29 greyscale images, each through a different filter which only passes IR light of a certain wavelength. The separate images are then assigned a colour; the longest wavelength is 'red' and the shortest 'blue', with the others in between. The 'colour' image is then formed from combining the separate filter images. In effect, the JWST's images are shifted up the electromagnetic spectrum from a part we can't perceive (IR) into the part we can (optical). Incidentally, this is how the images from the Hubble Space Telescope are formed, but in that case the filters are all at optical wavelengths and no shift is being performed. If the JWST colour images are not real, why make them? It's easier for scientists to analyse the images using these composite 'false-colour' images, and it's aesthetically pleasing to 'see' a representation of what JWST has observed. ***AGu***


IR
JWST captures infrared part of the electromagnetic spectrum
Infrared cameras take multiple pics in mono
Each picture is assigned a colour
Composite image is constructed

SIENNA HARRIS, VIA EMAIL

OWLS VS LARKS: WHEN IS THE BEST TIME OF DAY TO EXERCISE FOR SLEEP?



Exercise has been found to help improve sleep quality. Some of the mechanisms by which there is a positive impact include: reducing factors that can disrupt sleep, such as anxiety and obesity; and assisting the circadian rhythm, the natural sleep-wake cycle (to support consistent patterns). Recommendations, historically, included avoiding exercise close to bedtime in case sleep was disrupted by raising body temperature, for example. However, the evidence is not consistent that working-out late in the day is problematic – although it might be prudent to avoid vigorous exercise in the hour before you want to fall asleep.

As to whether advice should differ for larks, those 'morning types' who function at their best earlier in the day, as compared to owls, 'evening types' who function best later in the day, the answer depends, in part, on whether there is a desire to shift sleep timing.

Our body clocks are controlled by factors from within our bodies, and tweaked by influences from the world around us, such as the timing of exercise and our light exposure. Less is known about the impact of exercise on tweaking the body clock than light. However, it is possible that if an 'owl' is keen to fall asleep and wake up earlier (because, for example, of a specific work schedule), exercising early in the day – and with simultaneous light exposure – may help. On the other hand, if a 'lark' wishes to go to bed later (to allow for a longer evening), they might benefit from exercising later in the day, at some point between 7pm and 10pm, particularly if there is an exposure to light at the same time.

There could be an interaction between exercise timing, whether you're a lark or an owl, and sleep. One study found that exercising later in the day was more associated with a delayed sleep time for 'morning' than 'evening' types. A busy lifestyle can make it tricky for people to schedule exercise; if evening provides that opportunity, then exercise benefits outweigh the risks. ***AGr***

CROWDSCIENCE

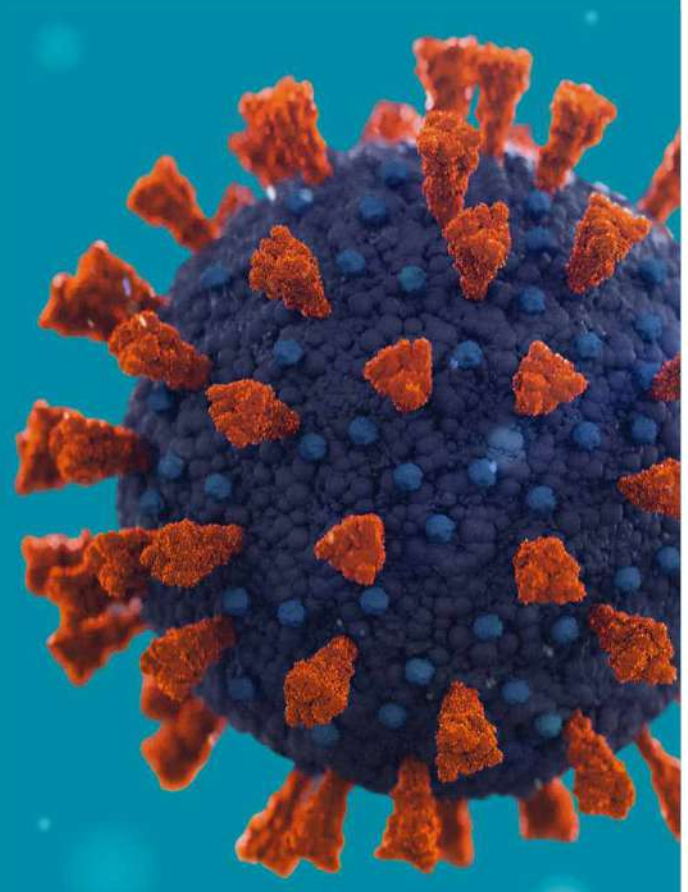
Every week on BBC World Service, *CrowdScience* answers listeners' questions on life, Earth and the Universe. Tune in every Friday evening on BBC World Service, or catch up online at **bbcworldservice.com/crowdscience**

ARE VIRUSES THE KEY TO FIGHTING INFECTIONS?

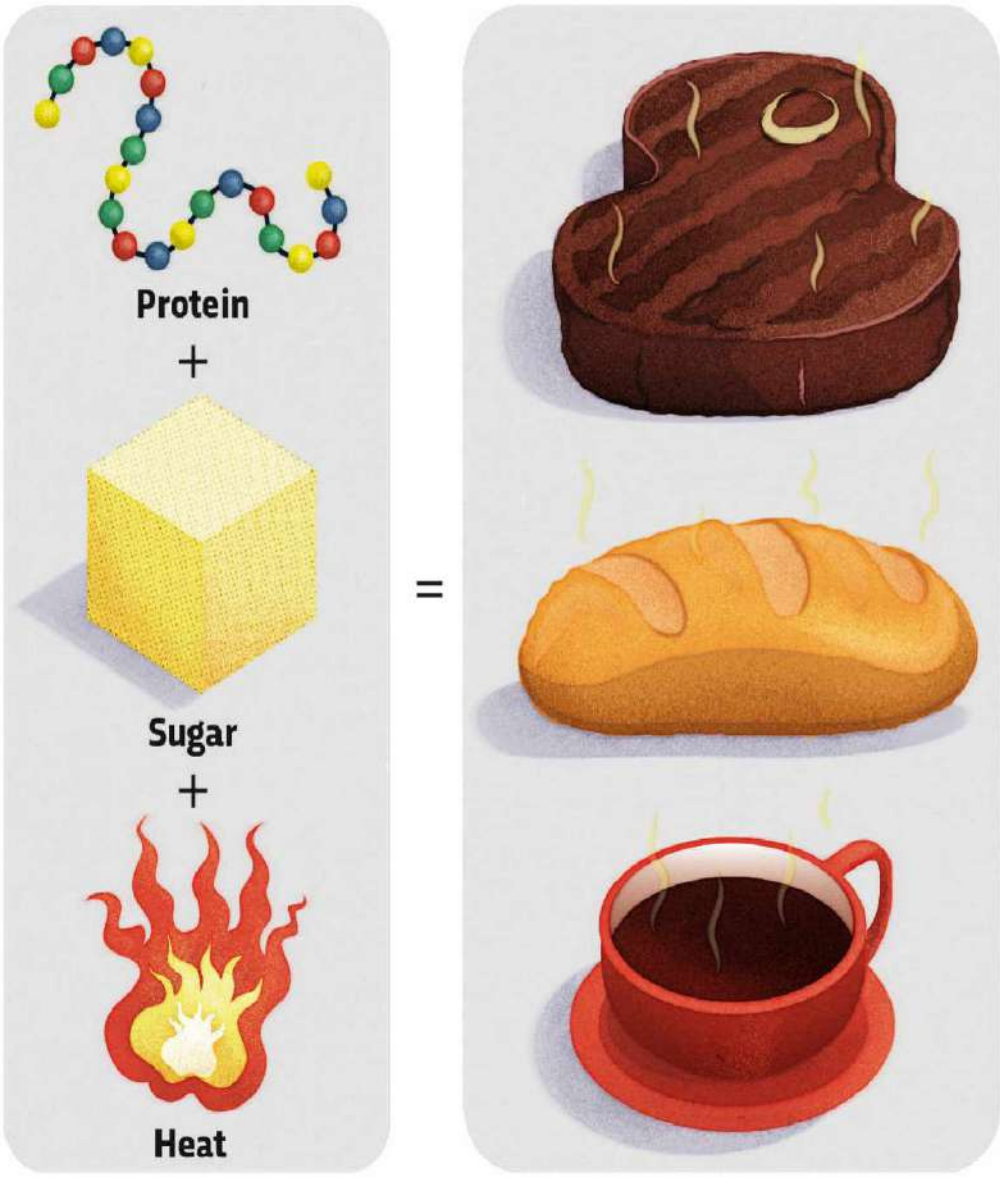
Yes and no – there are some viruses that are solely designed to fight bacterial infections, called bacteriophages (phages). These viruses attach to bacterial cells and inject their genome into the cell. The bacteria then produces the viral genome instead of its own, and this interferes with its ability to function, effectively halting the bacterial infection. There are thought to be billions of phages on Earth; they have co-evolved with the bacteria they prey on for millennia, keeping their numbers under control.

Phage therapy is the use of active phages to kill bacteria that cause human diseases, while leaving other bacteria unaffected. Phages have been around for a long time – they were officially discovered in 1915-17 and they have been used ever since as therapeutics, especially in countries like Russia, Belgium and Georgia. The reason why phage therapy was abandoned was mostly because of the discovery of antibiotics. But now there is a lot of hope that phages could help to destroy antibiotic-resistant strains of some of the most resilient superbugs in existence.

However, there are several obstacles to using phage therapy more widely. Phages are specific to particular bacteria, and those bacteria can evolve resistance. And it is proving challenging to recreate the way viruses behave in the body in lab environments. However, it is an exciting field to watch out for, and research is evolving into their potential applications. Time will tell whether these viruses are the key to fighting infection. *NM*



GETTY IMAGES X3 ILLUSTRATION: DANIEL BRIGHT



DAVID WALKER, VIA EMAIL

WHAT IS THE MAILLARD REACTION?

Often described as non-enzymatic browning, the Maillard reaction gives a wide range of cooked foods their appealing flavours and colours. Sped along by heat, the Maillard reaction is actually a series of reactions, starting with one between protein and a reducing sugar, such as glucose or fructose. The reactions produce flavour chemicals and browning in foods including fried onions, toast, steak and roasted coffee.

French chemist Louis Camille Maillard first reported the reaction between proteins and sugars in 1912. In recent decades, scientists have unearthed more of Maillard's detailed mechanisms.

When heat hits food, sugars react with the amino acids that make up proteins to form glycosylamine. This unstable chemical rearranges to create a ketosamine, setting off a cascade of further reactions to produce hundreds of new substances, some of which contribute to flavour and aroma. These includes pyrazines, which have a toasted flavour, along with meaty furans and sweet furanones. Finally, the reaction creates large polymer molecules called melanoidins, which give a brown colour.

In order to obtain Maillard products in a short time, the temperature should exceed 100°C, with an ideal range between 110°C and 170°C. If the temperature is too high, then bitter flavours can develop.

A downside of the Maillard reaction is that it creates a carcinogen called acrylamide as a by-product. Levels of this increase with longer cooking times. ***ED***

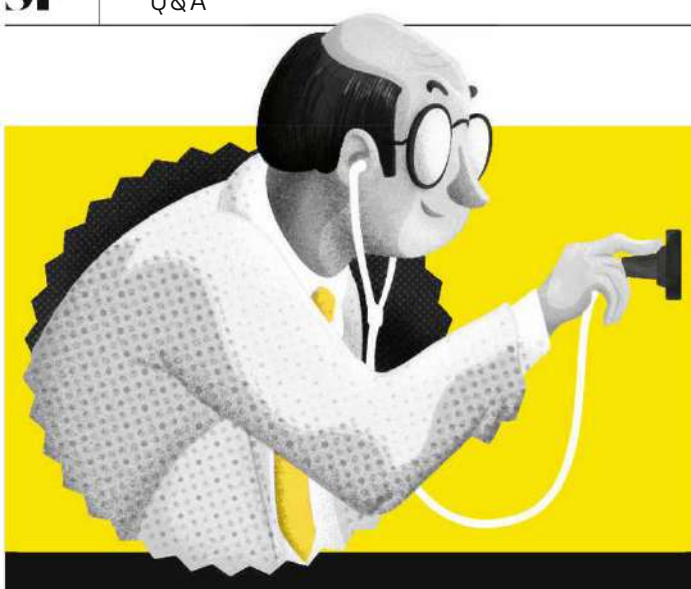
NATURE'S WEIRDEST CREATURES

HALLUCIGENIA

When scientists first studied the fossilised remains of this strange, spiky, worm-like creature, they couldn't tell its 'up' from its 'down', or its front from its back. Named for its 'bizarre and dream-like' appearance, hallucigenia was a finger-sized ocean-dweller that lived during the Cambrian Period around 508 million years ago. It belonged to a group called the panarthropods, which later gave rise to velvet worms, water bears and arthropods.

In 1977, British palaeontologist Simon Conway Morris determined that it had seven pairs of stilt-like legs sticking down, and seven pairs of mouth-tipped tentacles pointing up. Then more specimens were analysed, and this interpretation was turned upside down... literally. Scientists realised that the 'tentacles' were, in fact, claw-tipped legs that pointed down, and the 'legs' were actually pointy spines that protruded upwards.

Hallucigenia was now the right way up, but no one knew which end was the head. Then in the mid-2000s, modern microscopy methods were applied, and hey presto, the longer of the two 'sticky-out bits' was found to contain, not just eyes, but a mouth too. Behind the head, three hitherto unknown pairs of appendages were discovered, and the legs were shown to be jointless. Hallucigenia, it's thought, may have walked by altering the pressure of the fluid inside its legs, much like a modern-day starfish. ***HP***



DEAR DOCTOR...

HEALTH QUESTIONS DEALT WITH BY OUR EXPERTS

WHY DOES NASAL AND EAR HAIR BECOME MORE PROMINENT AS YOU AGE?

There isn't a consensus on this annoying phenomenon, but one explanation is related to the phases of hair growth.

Hair goes through three phases: an anagen phase when the hair is growing, a catagen phase when the hair stops growing, and finally a telogen phase where it is resting before it begins to grow again. Some scientists have suggested that nasal hair becomes more prominent as men age because of the influence of testosterone on the length of the anagen (growing) phase.

In men, during puberty, as testosterone levels increase, small hairs on the face, underarms, chest, legs, arms and pubic area turn into large hairs that remain in anagen for longer periods. To the annoyance of most men, later in life the follicles in the nose and ear become sensitive to testosterone and also increase in size, resulting in larger hairs. Paradoxically, scalp hair follicles of genetically predisposed men respond in the opposite way: they spend less time in the anagen phase, which leads to baldness.

However, the exact mechanism is still not well understood – more research has been done on why men lose their hair, rather than the problem of having too much. ***NM***

JOHN BOTHWELL, VIA EMAIL

CAN YOU MAKE A FUNCTIONING CANDLE FROM EARWAX?

No. Earwax, or cerumen, is not really a wax. It is mostly dead skin, with some long-chain fatty acids and cholesterol and other compounds binding it. Normal candles burn from the top as the wax melts in the heat from the flame, is drawn by capillary action up the wick, vaporises and burns. Earwax can't do this because keratin in the skin cells won't melt. Instead of a flame at the tip of the wick that burns down it, there would be a flame spreading across the surface until the whole candle was alight. ***LV***

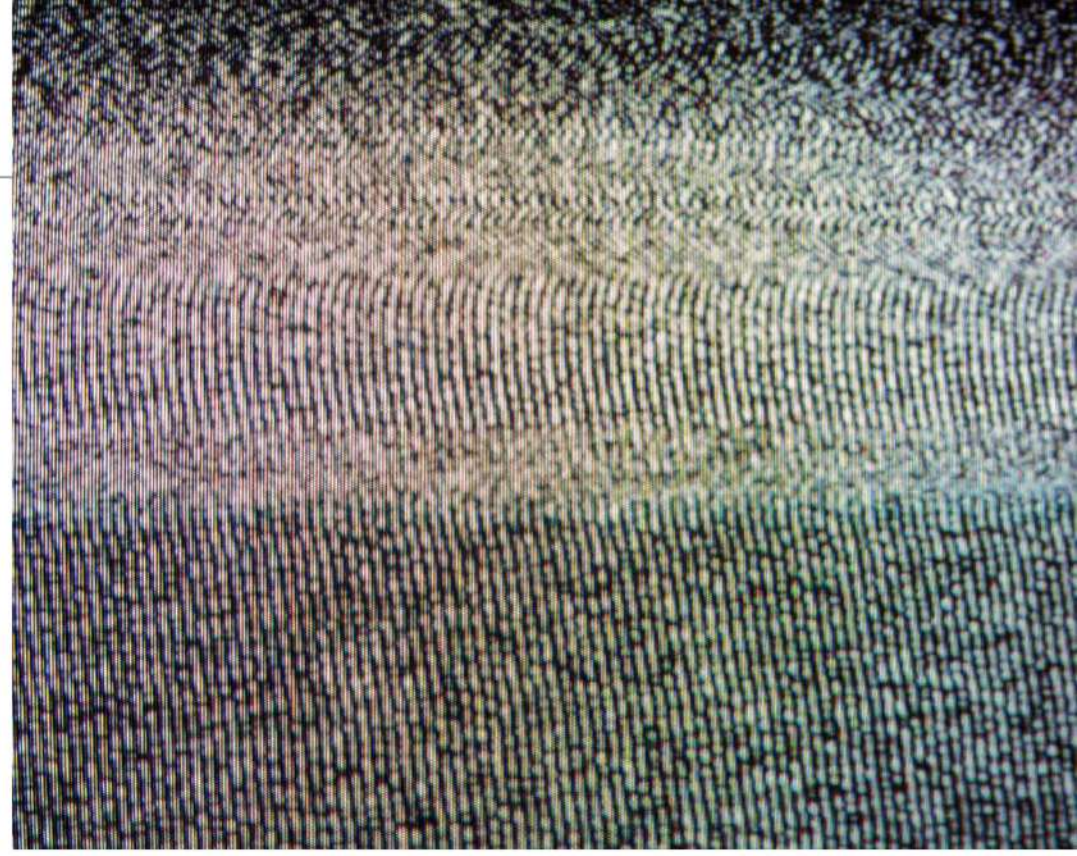
BELLA JACOBS, SALISBURY

HOW SOON CAN YOU CATCH COVID AGAIN?

We are seeing more people getting COVID-19 a second, third or fourth time. Often it is months between infections, but some people can catch it again within a few weeks. The likelihood of this occurring depends on two factors: how your immune system responds to the infection; and what variants are spreading locally. For most people, the infection generates an immune response that lasts three to 12 months. After that, some people are more likely to be infected again, unless immunity is boosted with vaccination. The reason that some people catch it again within a few weeks is down to local virus transmission. During the pandemic, some communities have had two or more variants spreading (like Delta and Omicron), with immunity from one not protecting from the other. Some people were re-infected in less than 90 days, with one person catching it again after 23 days. This is why COVID precautions are so important, even after being infected or vaccinated. ***JR***

ANNE-MARIE FERGUSON, VIA EMAIL

WHAT ARE WHITE, PINK AND BROWN NOISE?



Hang on a minute, you may be thinking, I've heard of white noise – that untuned radio sound that parents play to sleepless babes – but brown and pink? That's right, sound now comes in all the colours of Neapolitan ice cream and if you want to sample them you can just plug their names into YouTube or Spotify, but understanding the difference takes a bit more brain power. You need to think in terms of frequencies – the differences in pitch that give us musical notes. While white noise contains all the frequencies mashed together equally, brown and pink noise put more energy into the lower frequencies, the result being a bassier sound. Brown noise is the bassiest and, according to the some, the most soothing. Listening to it feels a bit like being awake on an aeroplane at night.

As for whether it's 'better', well, brown noise is the most on-trend noise colour, with TikTok users, especially those in the ADHD community, singing its praises. Many claim brown noise helps them to focus. Others use it in preference to white noise as a sleep aid. The reality is that scientists don't really know whether any of these noises work for the purposes that we're using them for, or whether they're safe in the long term.

Outcomes from sleep studies on white and pink noise vary wildly, a 2021 review article by University of Pennsylvania researchers found, with some research suggesting that playing continuous noise actually disrupts sleep rather than improving it. Claims about brown noise are even flakier since we hardly have any evidence. That doesn't mean it doesn't work though – we just don't know yet – but certainly the sounds that work for one person might not work for another. Still, having answered your question while listening to brown noise, I can personally attest to its soothing qualities! ***HB***

QUESTION OF THE MONTH

TONY H WORCESTER, VIA EMAIL

IF WE ARE ALL LIVING IN A SIMULATION, THEN WHAT IS REAL AND OUTSIDE OF THIS SIMULATION?

There is no way to know. This isn't just unknown in the way that the existence of life after death, or parallel universes is unknown; it is an unanswerable question. Let's suppose that we are in a computer simulation, either created by a higher intelligence or humans in the future. Now imagine that through some bug left in the code, we are accidentally able to step beyond the constraints of our programming and 'see' the simulation's raw scaffolding, like Neo in *The Matrix*. How would you be able to decide whether this lay outside the simulation, or was still part of it – as a joke or an Easter egg, put there by programmers?

Could you even definitively say that the columns of ones and zeros scrolling past your eyes proved that reality was a simulation at all? Maybe that's just what the Universe is made of, once you zoom all the way in past the atoms and quarks.

And even if you were able to unplug yourself and emerge blinking into the higher reality, how do you know this is what it is? Perhaps there is another reality around that, and so on. If none of these realities are reachable except in our imaginations, are they real? Reality comprises the things we can measure; everything else is fantasy or speculation.

Asking what lies beyond this reality is like asking who we were before being born. Shakespeare's Hamlet tells Horatio that there are more things in Heaven and Earth than are dreamt of in his philosophy. But it may be the other way round. Humans are good at dreaming up things that do not exist, so you can't use your ability to imagine something as evidence for it, one way or another. ***LV***

WINNER

The winner of next issue's *Question Of The Month* wins a pair of **Space Q45 headphones** worth £139.99. These adaptive noise-cancelling headphones will block out a wide range of sounds, from crying babies to plane noise. Plus, with 50 hours of playtime, you can travel on a long-haul flight without needing to charge.
uk.soundcore.com

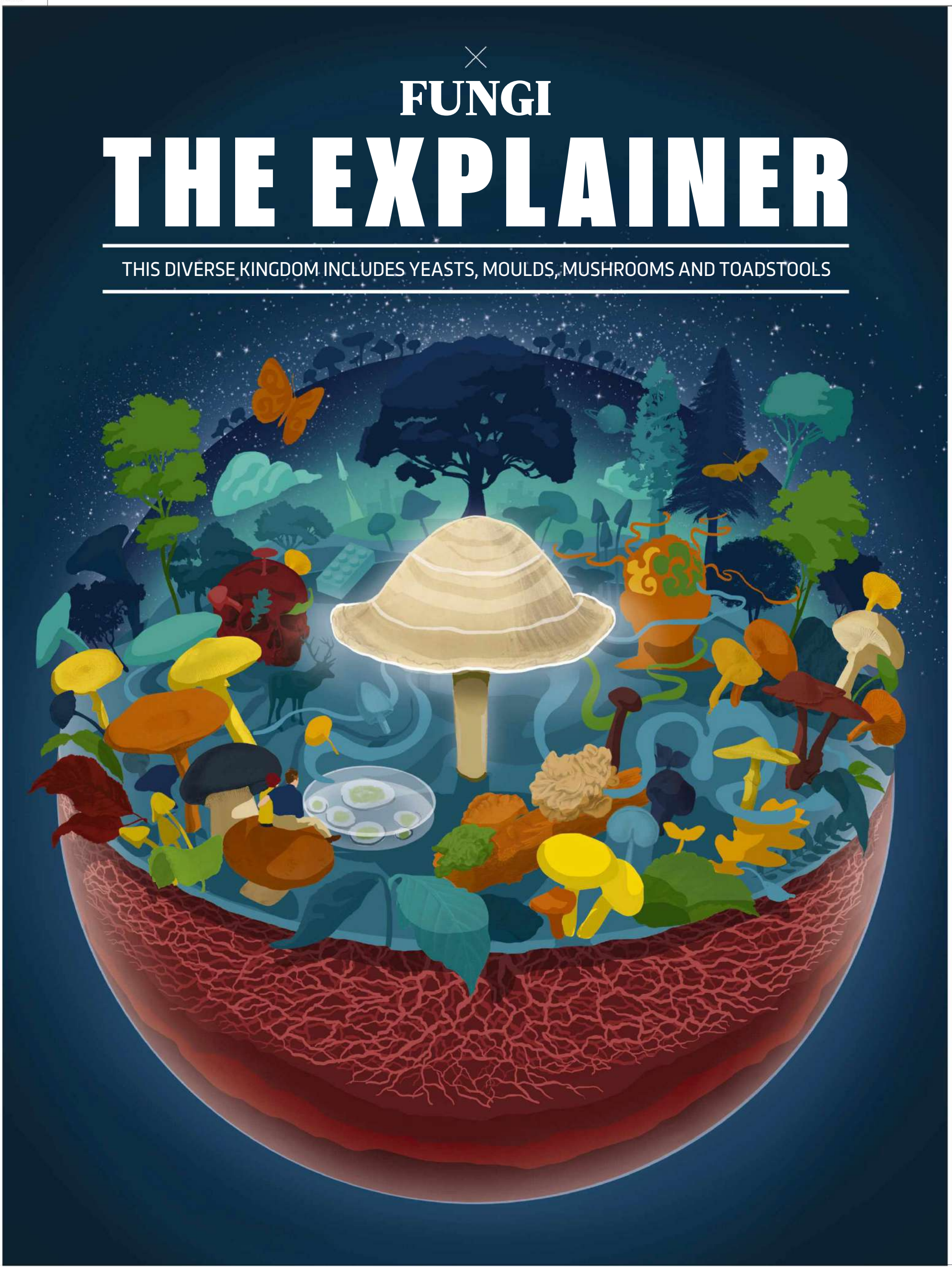
GETTY IMAGES X3 ILLUSTRATION: DANIEL BRIGHT

EMAIL YOUR QUESTIONS TO **QUESTIONS@SCIENCEFOCUS.COM**

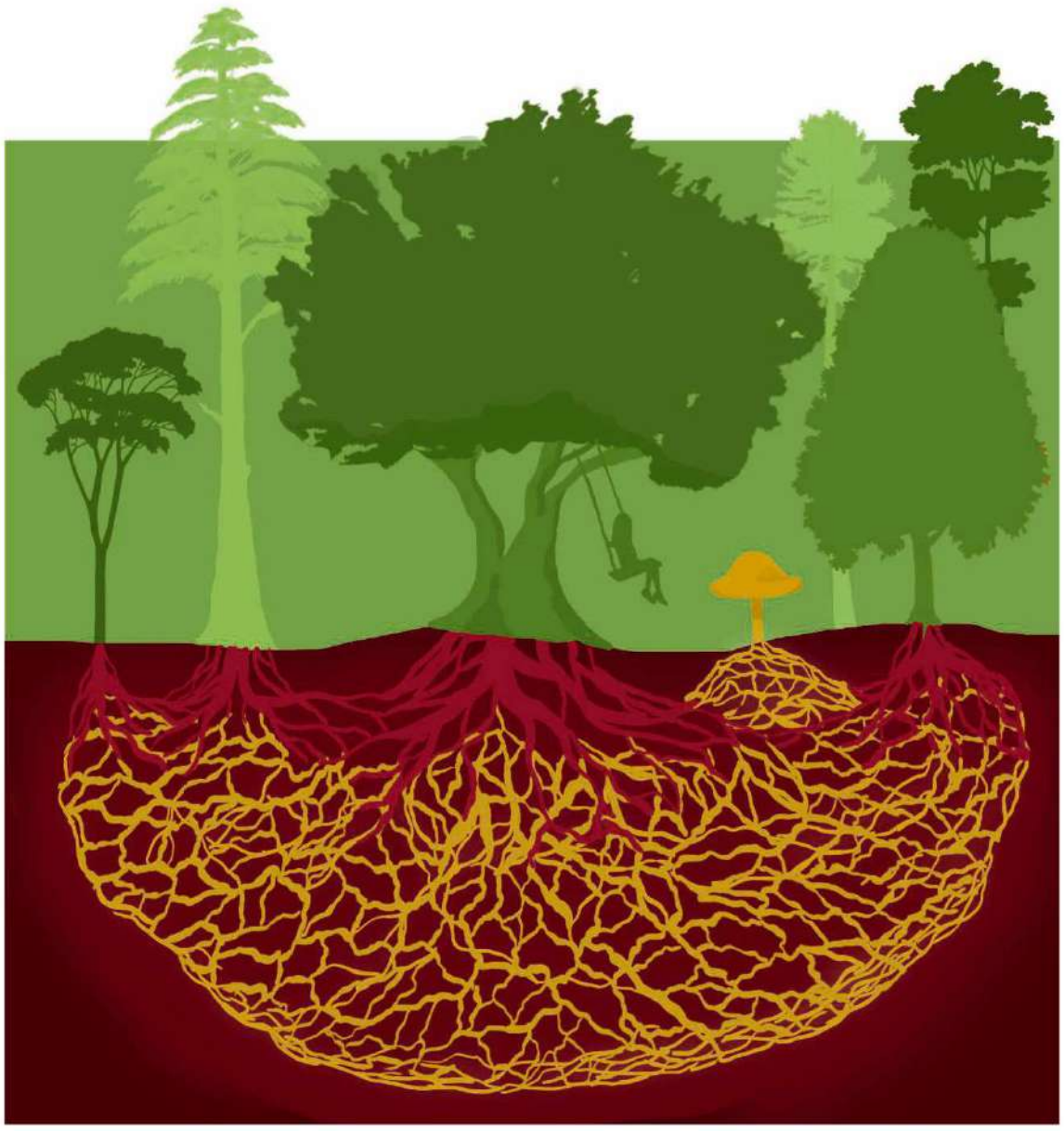
FUNGI

THE EXPLAINER

THIS DIVERSE KINGDOM INCLUDES YEASTS, MOULDS, MUSHROOMS AND TOADSTOOLS



ILLUSTRATIONS: SAM FALCONER



What are fungi?

Fungi are decomposing, fermenting, edible, toxic, carbon-sequestering, disease-causing, disease-curing, pollutant-busting, mind-bending, rain-generating, zombie-making marvels. They underpin almost all life on Earth, but are mostly situated underground and often overlooked.

When we think of fungi, mushrooms spring to mind, but these are just the small 'above ground' portion of the organism. Mushrooms are the fruiting body of the fungus, like the apples on a tree. Most of the fungus is hidden underground in the form of a branching network of tubular filaments called mycelium. If you took a teaspoon of healthy soil and lined up all the mycelium within it, it would stretch up to 10km.

Plant or animal?

Neither. Fungi belong to their own kingdom of life. It contains an estimated 2.2 to 3.8 million species, of which only 148,000 species or so have been described. Fungi used to be seen as simple plants, but scientists now realise that they are more closely related to animals.

Fungi come in a wide range of sizes. They can be single-celled and microscopic, like the yeast used in the beer-brewing industry, but they can also be multicellular and massive.

Spread over an astonishing 9km^2, the 'Humongous Fungus' in Oregon's Malheur National Forest is thought to be the world's largest living organism. It weighs hundreds of tonnes and is estimated to be between 2,000 and 8,000 years old.

How do fungi interact with plants?

Around 90 per cent of land-living plants have fungi living in their roots. A single plant can house dozens of different species. Mycorrhizal fungi, as they are known, send out fine fungal tubes that penetrate the root tips of plants. The result is a mutually beneficial relationship, where the fungi siphon sugars from the plant, and the plant receives water and nutrients in return.

The plant also becomes tapped into the much wider network of sprawling underground filaments, known as the Wood Wide Web. Plants near and far are connected by it. It enables them to share resources, such as nutrients and carbon, and also information. When broad bean plants are attacked by aphids, for example, they use the subterranean messaging system to send warning signals to neighbouring plants, which respond by releasing aphid-repelling chemicals.

How (and what) do they eat?

Fungi digest their food externally by secreting enzymes and then absorbing dissolved organic matter. Some fungi actively capture their prey. *Arthrobotrys oligospora* lures nematode worms to it by releasing molecules that smell like the worm's natural food. On arrival, the hapless worm is then dissolved and digested.

Many fungi feed on dead or decaying material, such as rotting logs or animal corpses. As such, they play a vital role in recycling the world's organic matter. Other fungi are parasites that feed on living organisms. Dutch elm disease (which affects trees) and ringworm (which affects people) are caused by parasitic fungi. All this is just for starters, as fungi can also digest rock, crude oil, plastics, cardboard and even explosive TNT.

"Spread over 9km^2, Oregon's 'Humongous Fungus' is thought to be the world's largest living organism"

Where do they live?

Just about everywhere, in just about everything... living organisms, soil, air, water, rock, even nuclear waste sites. Fungi found growing at the ruined Chernobyl nuclear reactor in Ukraine can absorb high levels of radiation, which they use as a source of energy. Now scientists are exploring whether fungi like this could help to protect people from radiation during deep space missions.

How do they reproduce?

They can reproduce sexually, asexually (without sex) and parasexually (where tiny filaments called hyphae fuse together). Often, reproduction involves the production of spores, which are a bit like the seeds of a plant. Spores are dispersed into the environment, enabling the fungus to colonise new areas. Some fungi eject spores explosively, accelerating up to 10,000 times faster than a post-launch Space Shuttle. Others create their own microclimates. As water evaporates from the gills of a mushroom, it can create an updraught that helps to lift spores into the air.

When did they first evolve?

Around a billion years ago. The first fungi would have been small, aquatic, single-celled organisms. Roughly 500 million years ago, they helped plants move out of the water onto the land, by acting as their root systems. Then 100 million years later, fungi were the tallest living things on Earth. *Prototaxites* was a massive, trunk-like fungus that grew up to nine metres in height.

ILLUSTRATIONS: SAM FALCONER

Can you farm fungi?

Yes, but for further advice, please ask the leafcutter ant. These industrious insects feed the leaf fragments they collect to the fungi that they cultivate inside their enormous underground nests. The fungi are fed to the ant's larvae, and the adults keep the resource in tiptop condition by obsessively monitoring it, feeding it and keeping it pest free.

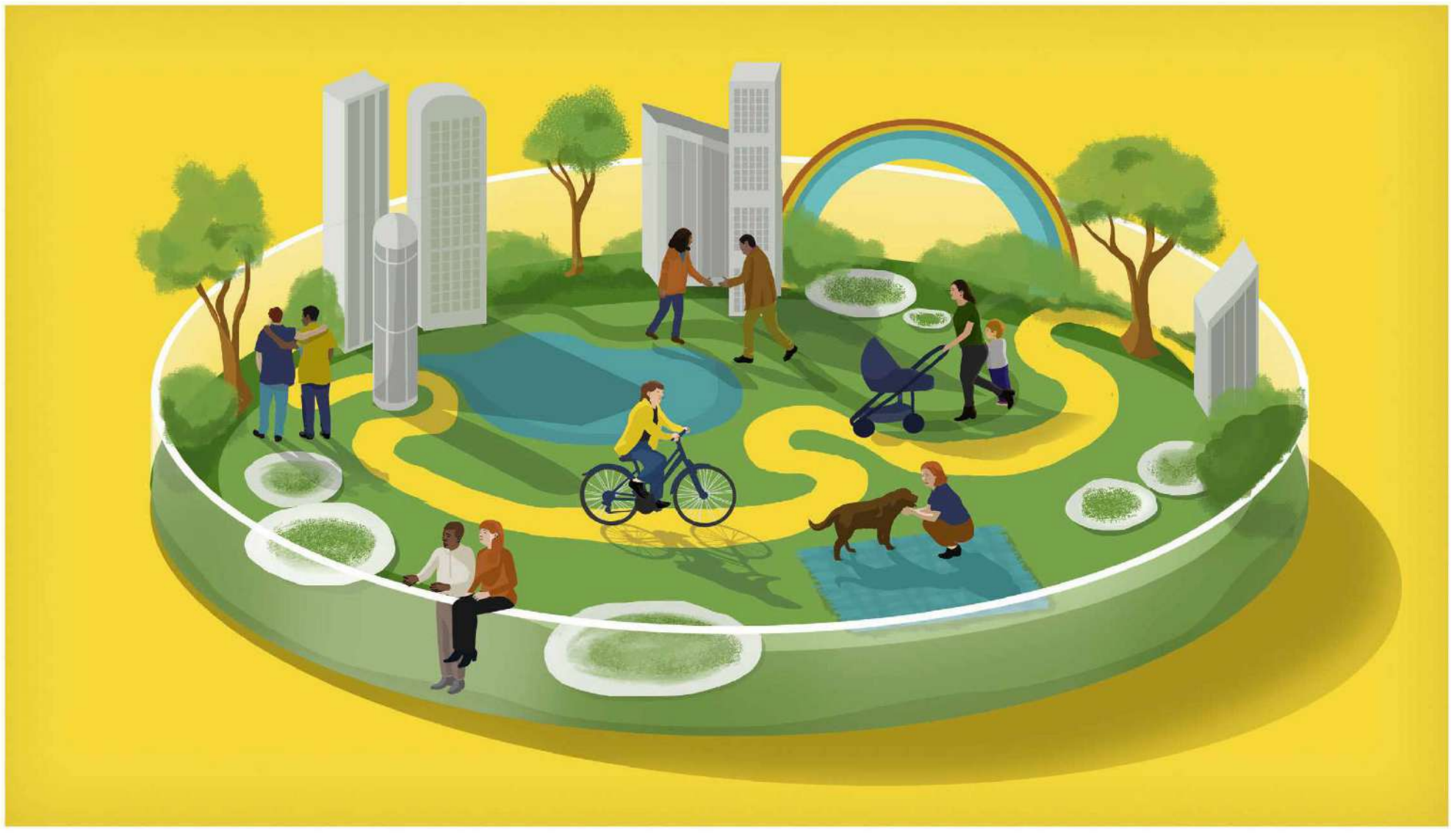
Can fungi make zombies?

Yes, the unlucky carpenter ant can become the victim of *Ophiocordyceps unilateralis*, the zombie-ant fungus. At the start of an extraordinary sequence of events, the brain of an infected ant becomes hijacked, prompting it to climb a nearby plant and bite into a leaf that is exactly 25cm above the ground, at just the right temperature and humidity for the fungus to grow. The fungus eats the ant's internal organs and extends a long stalk through its head, which then bursts and rains spores down onto any ants below. The cycle of zombification continues.

What is the most helpful fungus?

Fungi can be killers, but they can also save lives. The antibiotic penicillin is produced by the fungus *Penicillium*. It was discovered, by accident, almost 100 years ago, when Alexander Fleming spotted a bacteria-slaying mould growing on a forgotten Petri dish. Since then, penicillin has saved hundreds of millions of lives, added 20 years of life expectancy across the world, and paved the way for countless procedures, such as Caesareans and organ transplants, to be performed with a reduced risk of infection. *Penicillium* is also helpful in food production. *Penicillium camemberti* and *Penicillium roqueforti* are used in Camembert, Brie, Roquefort and many other cheeses, while *Penicillium nalgiovense* is used to boost the flavour of certain sausages and hams.

"Fungi can be killers, but they can also save lives. The antibiotic penicillin is produced by the fungus *Penicillium*"



What is the deadliest fungus?

Responsible for 90 per cent of the world's mushroom-related fatalities, the deathcap mushroom is officially the world's most poisonous mushroom. It looks like some edible mushrooms, such as the puffball and paddy straw, but eating it can lead to organ failure, seizures, coma and death.

Elsewhere, the chytrid fungus is decimating the world's amphibians. It enters the animals' bodies through their skin, upsets their fluid balance, and kills by causing heart failure. Spread around the world by the commercial trade in amphibians, it's now found on every continent except Antarctica (where there are no amphibians). Over the past 50 years it has caused the decline of more than 400 amphibian species, and the extinction of 90.

How could fungi be used in the future?

There are so many opportunities for fungi. Fungi can be used to break down pollutants, such as pesticides, plastics and crude oil. Mycelium mats can filter contaminants, such as heavy metals, from dirty water. Fungi can be used to break down waste products from food production and the building sector, and build sustainable, carbon-neutral materials, such as fabrics and construction materials. The *Trichoderma* fungus can turn crop waste into bioethanol, while elsewhere in agriculture, fungi are being used to boost crop growth and help control disease.

"The chytrid fungus has caused the decline of over 400 amphibian species, and extinction of 90"

DR HELEN PILCHER
(@HelenPilcher1)
Helen is a freelance science writer and performer.

5 WAYS THAT FUNGI AFFECT OUR LIVES

1.

Itaconic acid, derived from *Aspergillus* fungi, is used in a wide range of industries. Products include LEGO, plastic car parts, printing inks, UV coatings and synthetic rubber.

2.

More than 200 species of fungi are thought to be hallucinogenic. Psilocybin, found in magic mushrooms, is being explored as a treatment for depression and anxiety.

3.

Adidas has developed a pair of trainers made from mycelium, and Stella McCartney has premiered a 'panelled bustier and utilitarian trouser set' fashioned from the same fungal product.

4.

Fungi can influence the weather. When their spores occur in clouds, they can seed raindrops and spur the formation of ice crystals, which can fall as snow, sleet or hail.

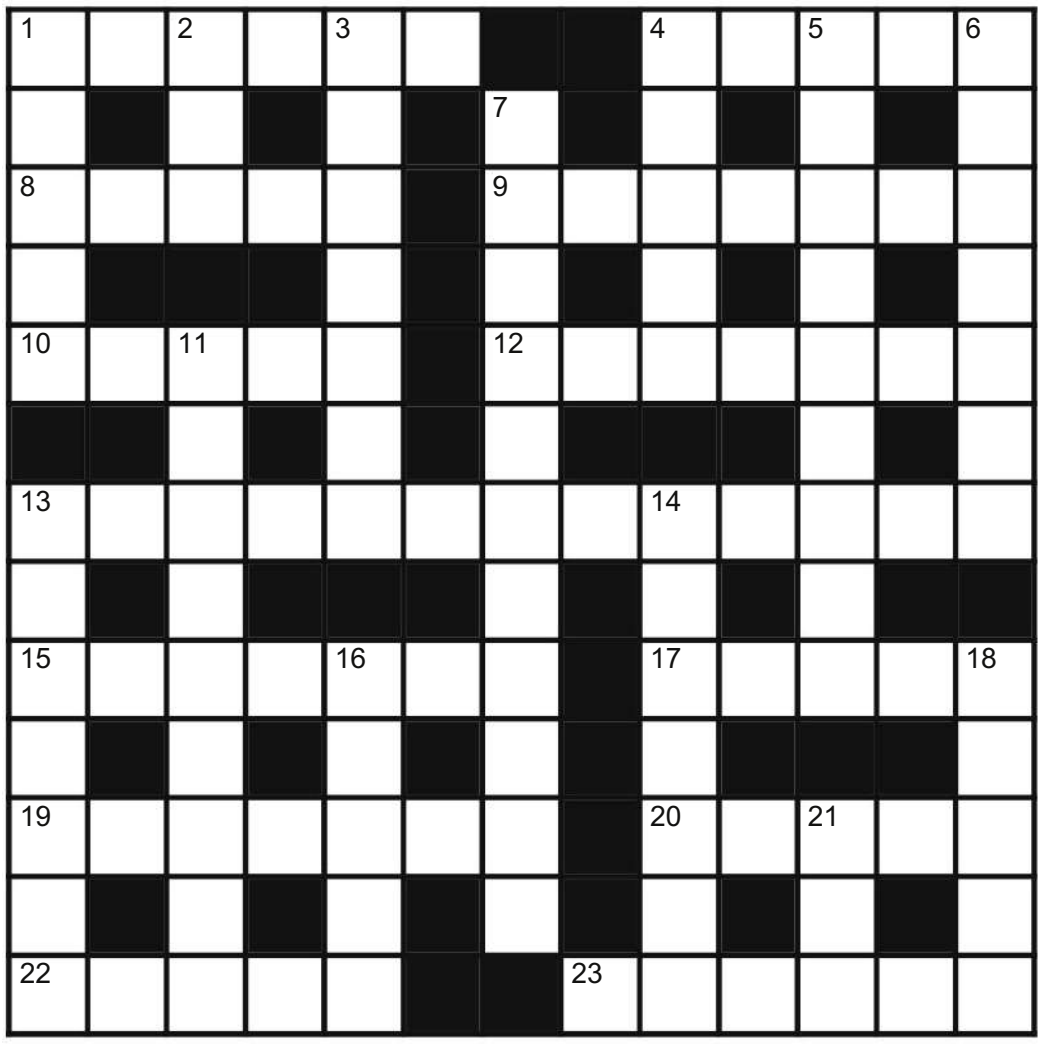
5.

The global market for edible mushrooms is worth over $42bn per year. But out of the estimated 10,000 mushroom species found worldwide, only about 350 species are known to be edible. SF

ILLUSTRATIONS: SAM FALCONER

CROSSWORD

PENCILS AT THE READY!



ACROSS

1 Supporter seen regularly in paper (6)
4 About to rule out being savage (5)
8 Intolerant person to leave during section (5)
9 Yokel is nice, but left out (7)
10 Quick to knock with identification (5)
12 Castigate a quiet hooligan outside (4,3)
13 Rascal in sandy, rough Spanish territory (6,7)
15 Seeking a sport (7)
17 Beneath French and German articles (5)
19 Care about time and space (7)
20 Provided information around four (5)
22 Surpass a large size, say (5)
23 Head of finance managed church in the country (6)

DOWN

1 Log taxi with hesitation (5)
2 Member of whole group (3)
3 Entertainer switched to drama (7)
4 Men's leather trousers (5)
5 Simple defence group dared no revolution (9)
6 Untruths about baby – that's an understatement (7)
7 Duration being new to European competition (8,3)
11 Angry epic about to get accolade (9)
13 Game never ends – it's a farce (7)
14 Garden item for lazy person (7)
16 At home with a couple of students added together (2,3)
18 Get up, having new hair treatment (5)
21 Di left sofa in vehicle (3)

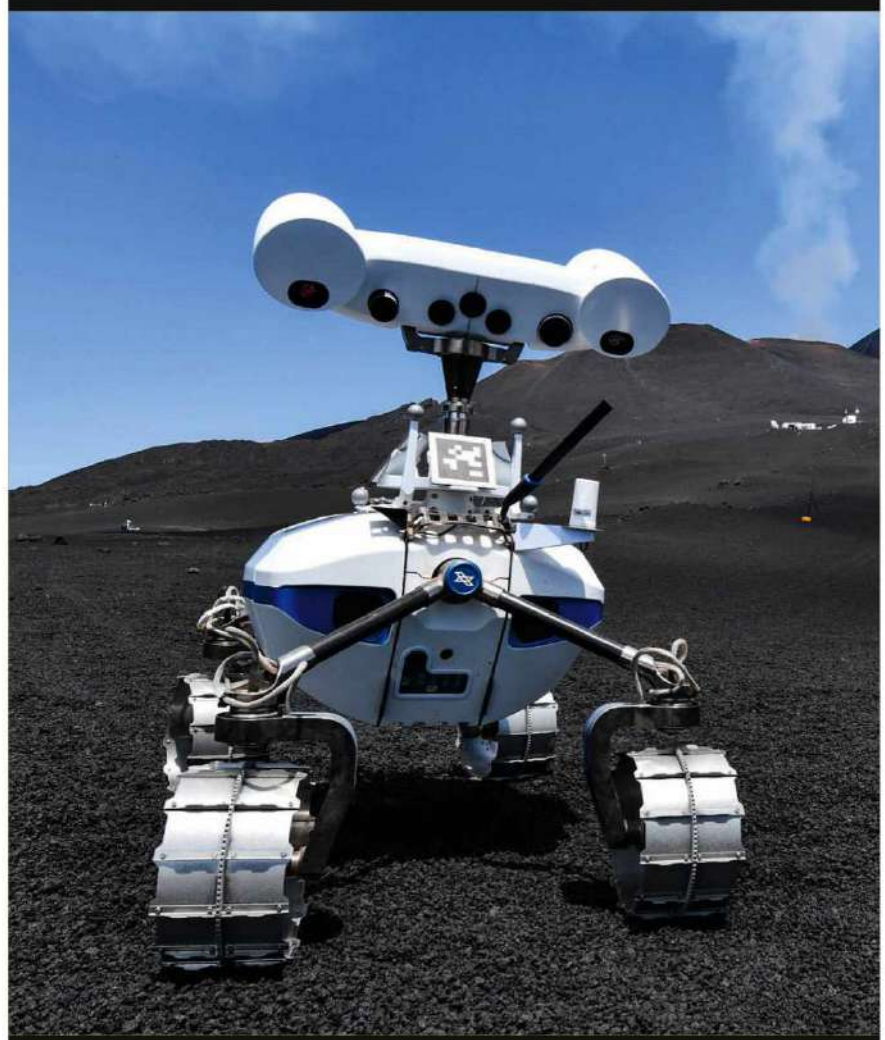
DLR

ANSWERS

For the answers, visit **bit.ly/BBCFocusCW**
Please be aware the website address is case-sensitive.

NEXT ISSUE

THE ARCHES PROJECT



PLUS

ROOTING THROUGH TUTANKHAMUN'S ROOMS

Are any hidden chambers still waiting to be found in King Tut's tomb?

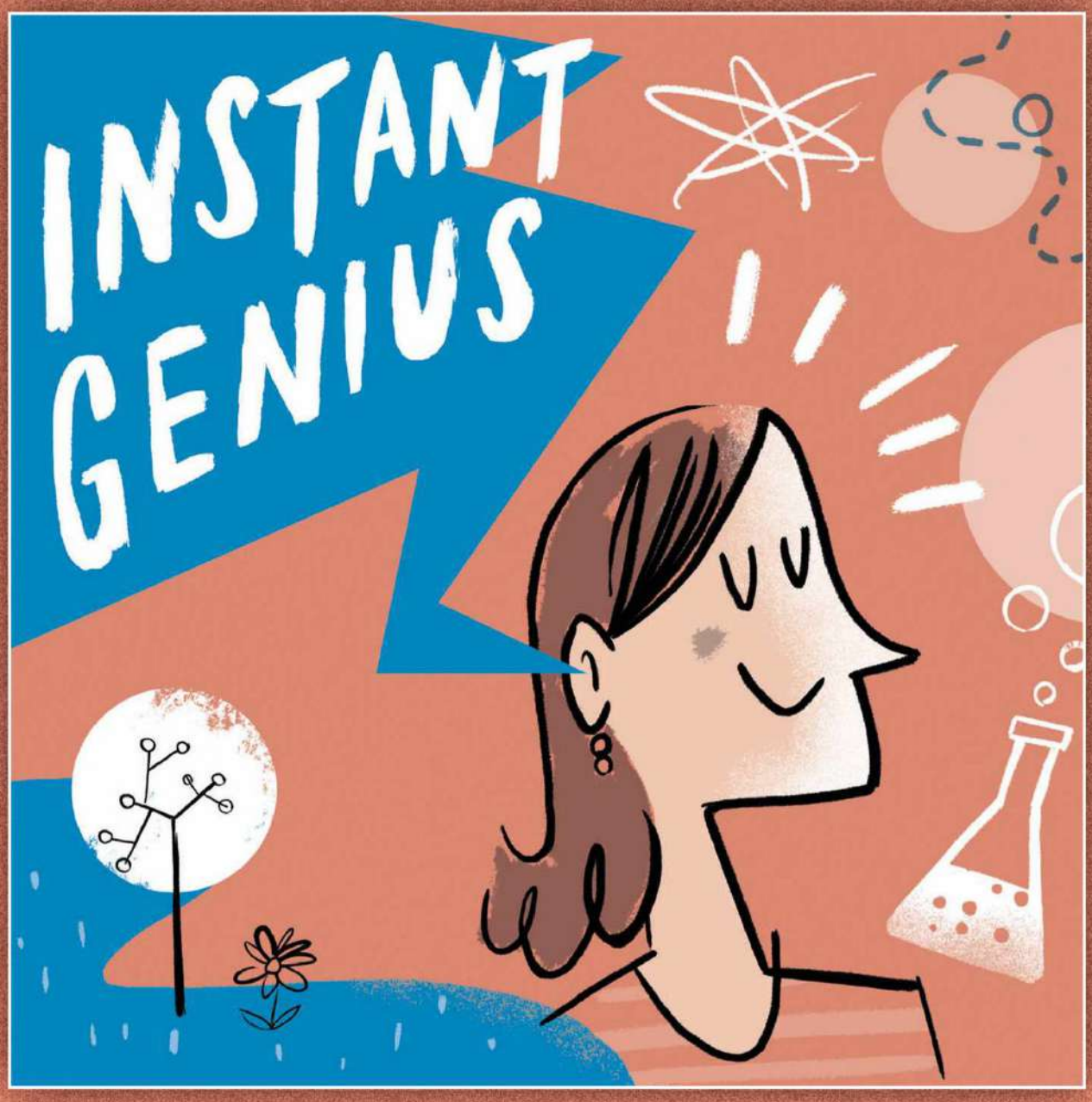
DEMENTIA EXPLAINED

ON SALE 9 NOV

SF

DON'T JUST READ THIS MAGAZINE... LISTEN TO IT TOO

Discover the weekly podcast from the team behind *BBC Science Focus*, available on Acast, Spotify, Apple Podcasts and all other podcast platforms
sciencefocus.com/instant-genius-podcast



FEATURING

SEASHELLS
with ***Dr Helen Scales***

BEE COGNITION
with ***Prof Lars Chittka***

LIFE ON MARS
with ***Lewis Dartnell***

ARTEMIS
with ***Libby Jackson***

POPCORN SCIENCE

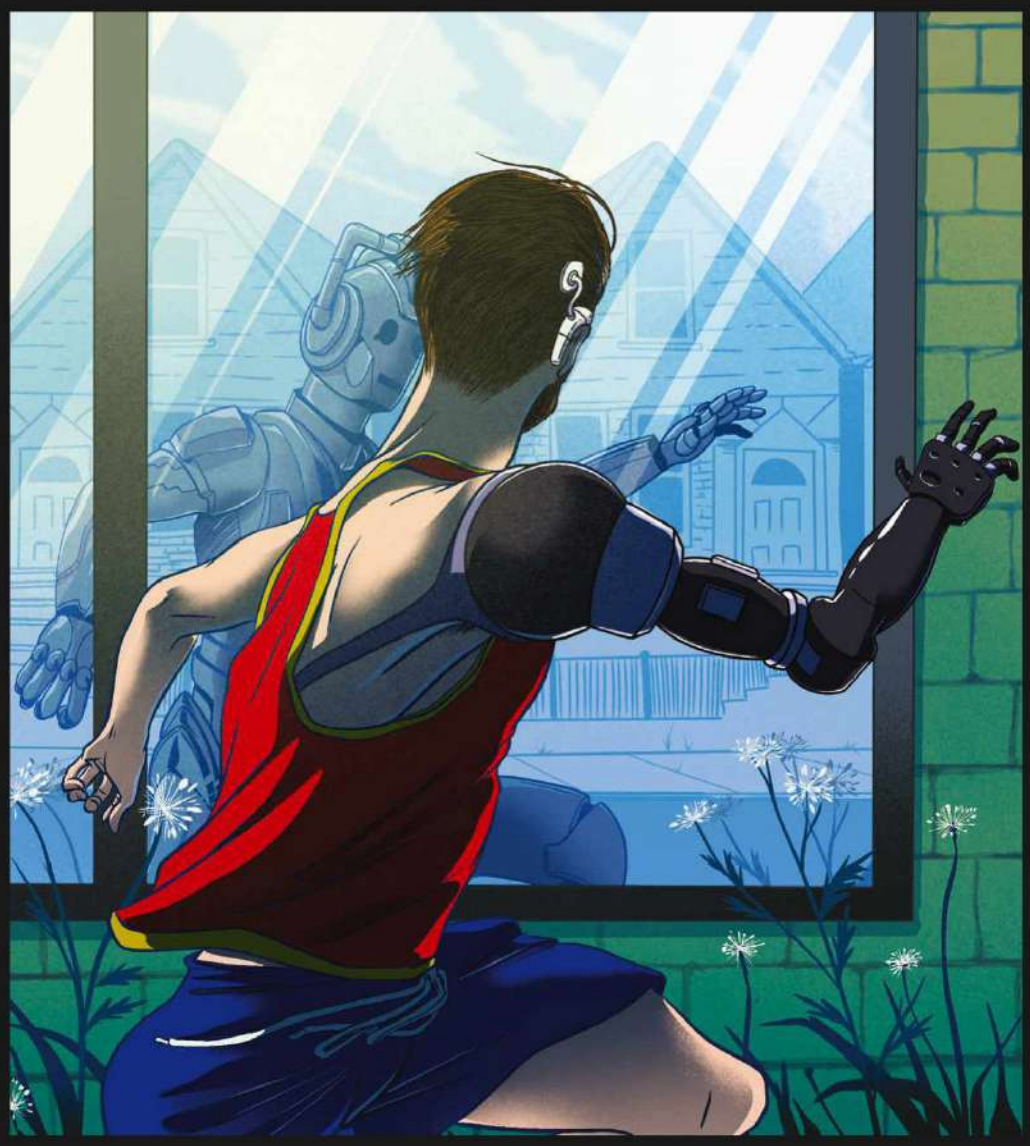
BBC ONE

Watch the *Doctor Who* Centenary Special this October. Check *Radio Times* for details.

Could we become cold, ruthless Cybermen?

We assess the likelihood of humanity turning into cyborgs, like Doctor Who's infamous foe

by STEPHEN KELLY



When they were first created in the 1960s, *Doctor Who*'s Cybermen were a vision of a nightmare future, where humanity has become more machine than flesh. But as time goes by, and more advances are made in bionics and neural implants, this vision doesn't seem so far-fetched. As the Cybermen return for *Doctor Who*'s Centenary Special, Timothy Constandinou, professor of bioelectronics at Imperial College London and the UK Dementia Research Institute, is cautious about us being upgraded to a race of cyborgs.

"We're very far from the science fiction notion of enhancement," says Constandinou. "All implants available now, either clinically or commercially, exist to solve medical problems. But if you look at something like cochlear implants, which help people who are profoundly deaf to hear, or experiments with brain computer interfaces, which could help people with locked-in syndrome communicate using neural signals, those are forms of enhancement." For anything beyond medical use, however, he thinks that, "from an ethical and regulatory perspective, it would be hard to see the light of day. There's a lot of concern in government about the use and misuse of technology."

Even if a company was to get the go-ahead to turn us into Cybermen, current technology is limited. Take artificial limbs, such as a bionic arm. Constandinou refers to a million dollar 'Luke Skywalker arm' that could be controlled by the user through a nerve that had been reconnected to muscle in the chest.

"The problem was that you always had to be looking at what you're doing, because the arm offered no sensory feedback," he says. "Many Luke arm users stopped using them and went back to their prosthetic hook." Creating an arm that can sync with the brain is a huge technical task, according to Constandinou. "If a nerve is 1mm in diameter and has 100,000 nerve fibres in that 1mm, we currently have no way to connect onto those 100,000 fibres in a reliable way that will last safely for years. If we could, I'm quite confident that we could create the most natural control of a prosthetic limb."

Cybermen have not only tampered with their bodies, but also with their minds, and each one has an emotional inhibitor. Brain implants are not as fanciful as seamless robotic limbs. Last year, researchers at the University of California surgically implanted a device into a patient's brain that had been calibrated to deliver a pulse of electric stimulation each time it detected specific neural signs of depression. Constandinou says that he can see similar technology being used in the future.

"If we're looking at what we're trying to treat today, I would say neurodegeneration is a possible area – we are already seeing how deep brain stimulation implants in people with Parkinson's disease are treating symptoms such as tremor or stiffness," he says.

The issue with implants is that they are large and need invasive surgery. Constandinou holds up an implant the size of an iPhone. "My area of research is in making this the size of a peppercorn," he says. "So going down around 1,000 times in volume to a future where it's injectable… the only way to reach a larger population is to reduce invasiveness."

The Cybermen have no such concerns. **SF**

VERDICT

To turn someone into a Cyberman would just be too invasive, and the tech is unlikely to be around for a long time. You can rest easy.

by STEPHEN KELLY (@StephenPKelly)
Stephen is a culture and science writer, specialising in television and film.

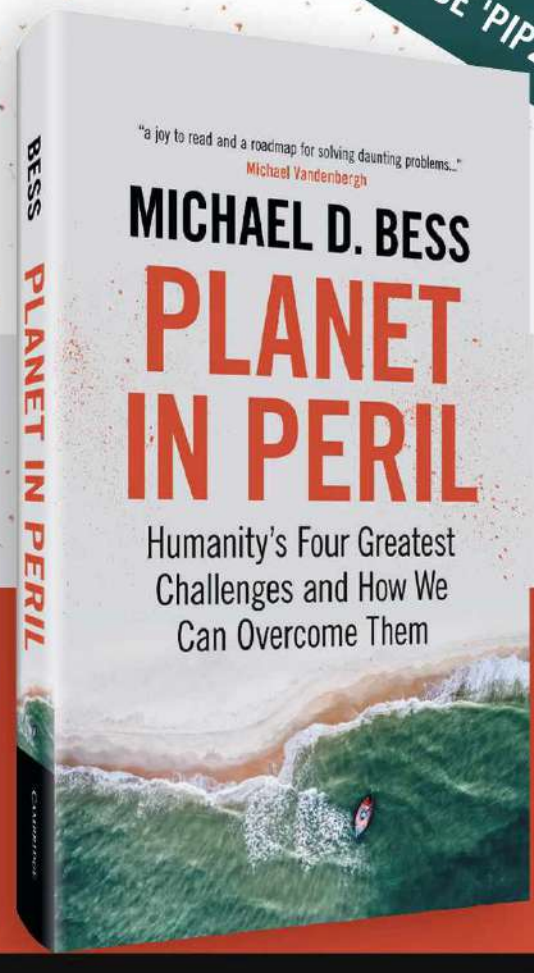
ILLUSTRATIONS: ADAM GALE MAIN ILLUSTRATION: ADAM MAZUR

20% OFF
WITH DISCOUNT CODE 'PIP20'

MICHAEL D. BESS

PLANET IN PERIL

Humanity's Four Greatest Challenges and How We Can Overcome Them


"a joy to read and a roadmap for solving daunting problems..."
Michael Vandenbergh
MICHAEL D. BESS
PLANET IN PERIL
Humanity's Four Greatest Challenges and How We Can Overcome Them
BESS
PLANET IN PERIL

Award-winning historian Michael D. Bess writes in vivid prose, drawing on illustrative historical examples. Eleven fictional vignettes describe concrete scenarios for future approaches to confronting the top four mega-dangers facing humankind. This book offers the general reader an exciting combination of breadth, rigor, and accessibility.

'In *Planet in Peril*, Michael Bess brings his singular voice, intellectual courage, and good judgment to bear on the four mega-dangers facing humankind – climate change, nuclear weapons, pandemics, and artificial intelligence. He avoids the simplistic thinking that characterizes too much of the public debate on these issues and offers insightful, viable solutions. It is one of those rare books that is both a joy to read and a roadmap for solving daunting problems.'
Michael Vandenbergh, *Vanderbilt University*

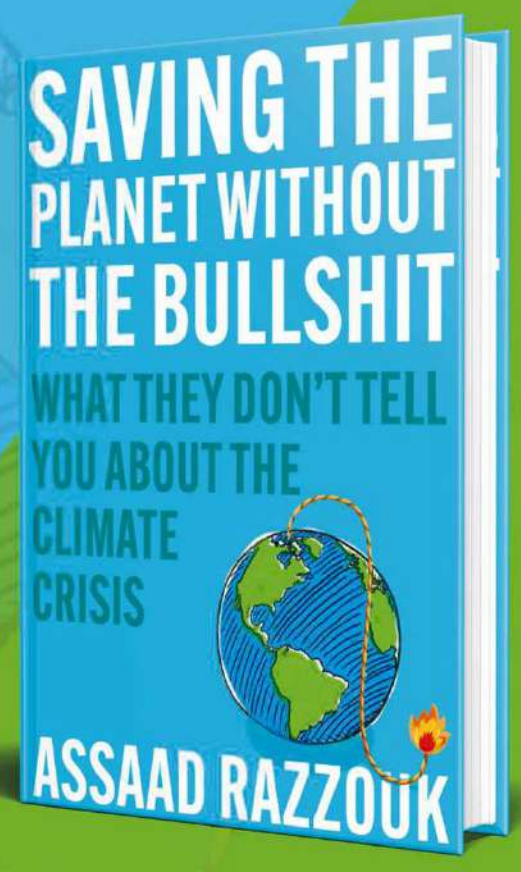
9781009160339 | £20.00 GBP $24.95 USD | HARDBACK | OCTOBER 2022
CAMBRIDGE.ORG/PLANETINPERIL

CAMBRIDGE UNIVERSITY PRESS

GOING VEGAN TO GO GREEN? DON'T BOTHER.
CARBON OFFSETTING? NOT HELPFUL.

What are the real things we can do to mitigate the climate crisis?
One of the world's biggest green influencers presents the most effective measures we can take to save our planet.

'Punchy, provocative' David Shukman
'Eye-popping and essential' Rowan Hooper
'A must-read' Peter Stott



OUT NOW

koa

at electric boulevard

love where you live

a new collection of studios, one-bedroom and two-bedroom apartments launching this october

apartments from £550,000
sales enquires: +44 (0)20 3944 5724

@batterseapwrstn
batterseapowerstation.co.uk

BATTERSEA POWER STATION